Drivers and Mechanisms of Peat Collapse in Coastal Wetlands

Benjamin J. Wilson[1], Sean P. Charles[1], Shelby Servais[1], Steve Davis[2] John Kominoski[1], Evelyn Gaiser[1], David Rudnick[3], Fred Sklar[4], and Tiffany Troxler[1]

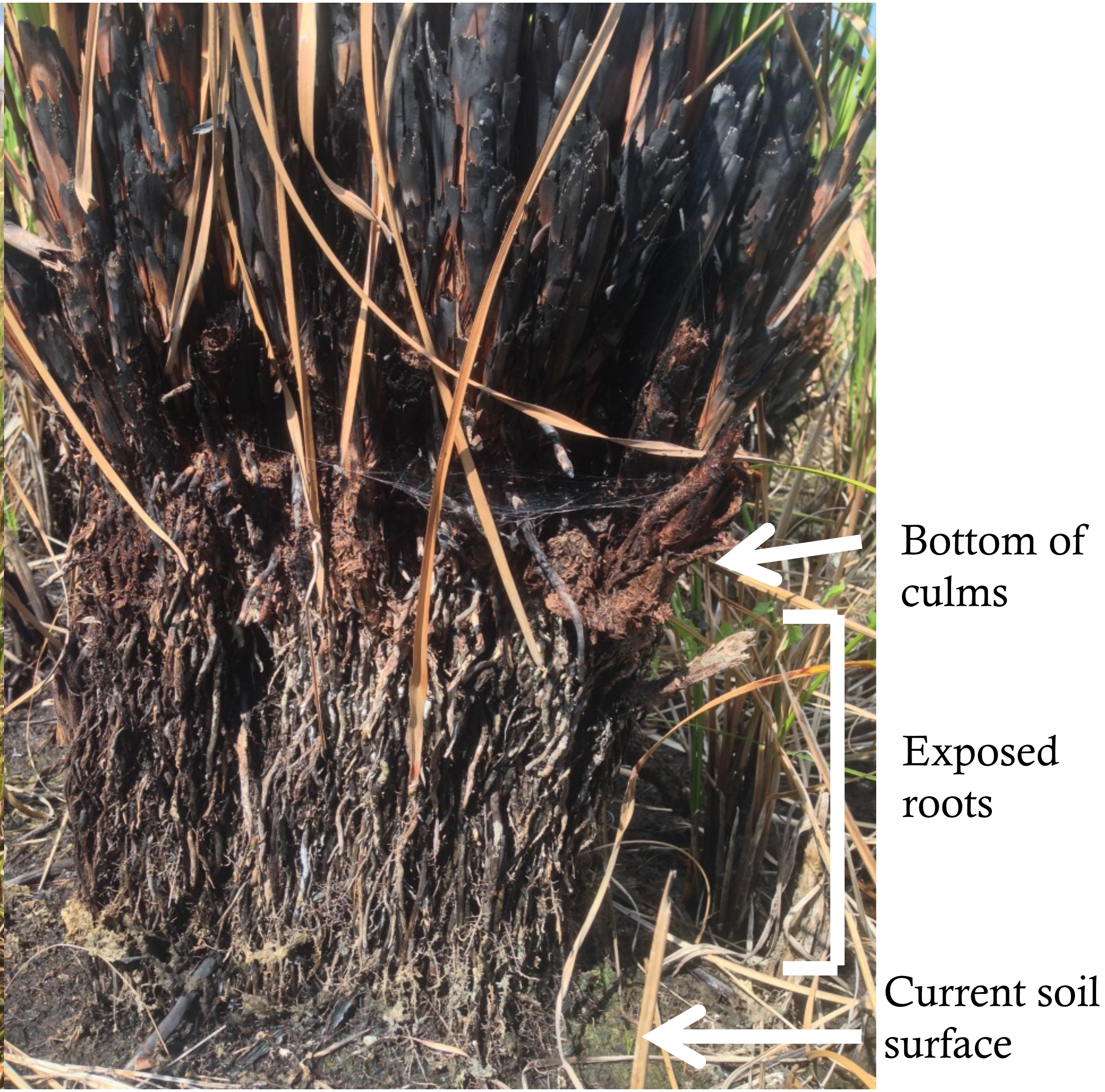
[1]Florida International University

[2]Everglades Foundation

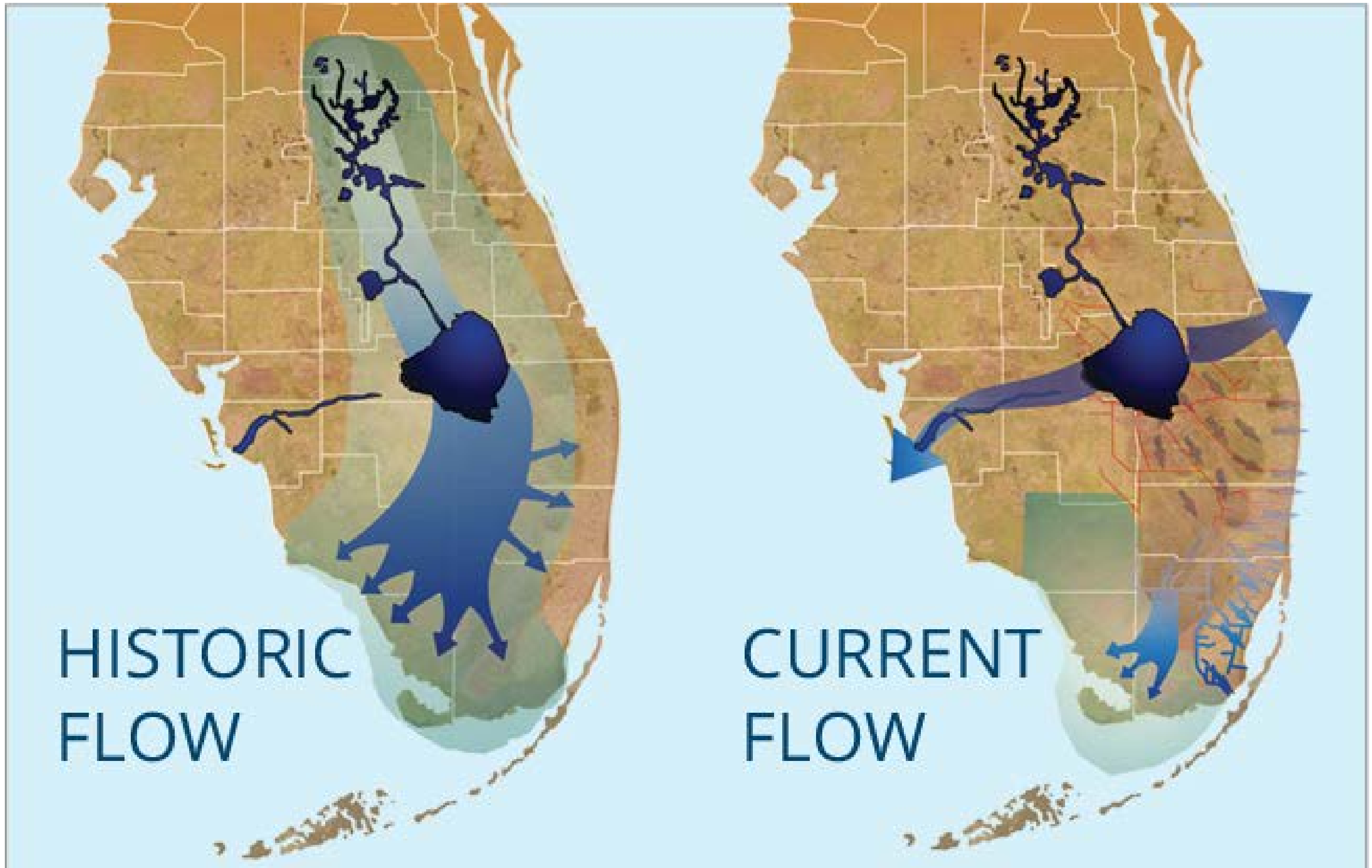
[3]Everglades National Park

[4]South Florida Water Management District

What is “Peat Collapse”?



Reduced freshwater flow has exacerbated saltwater intrusion and drought in the coastal Everglades

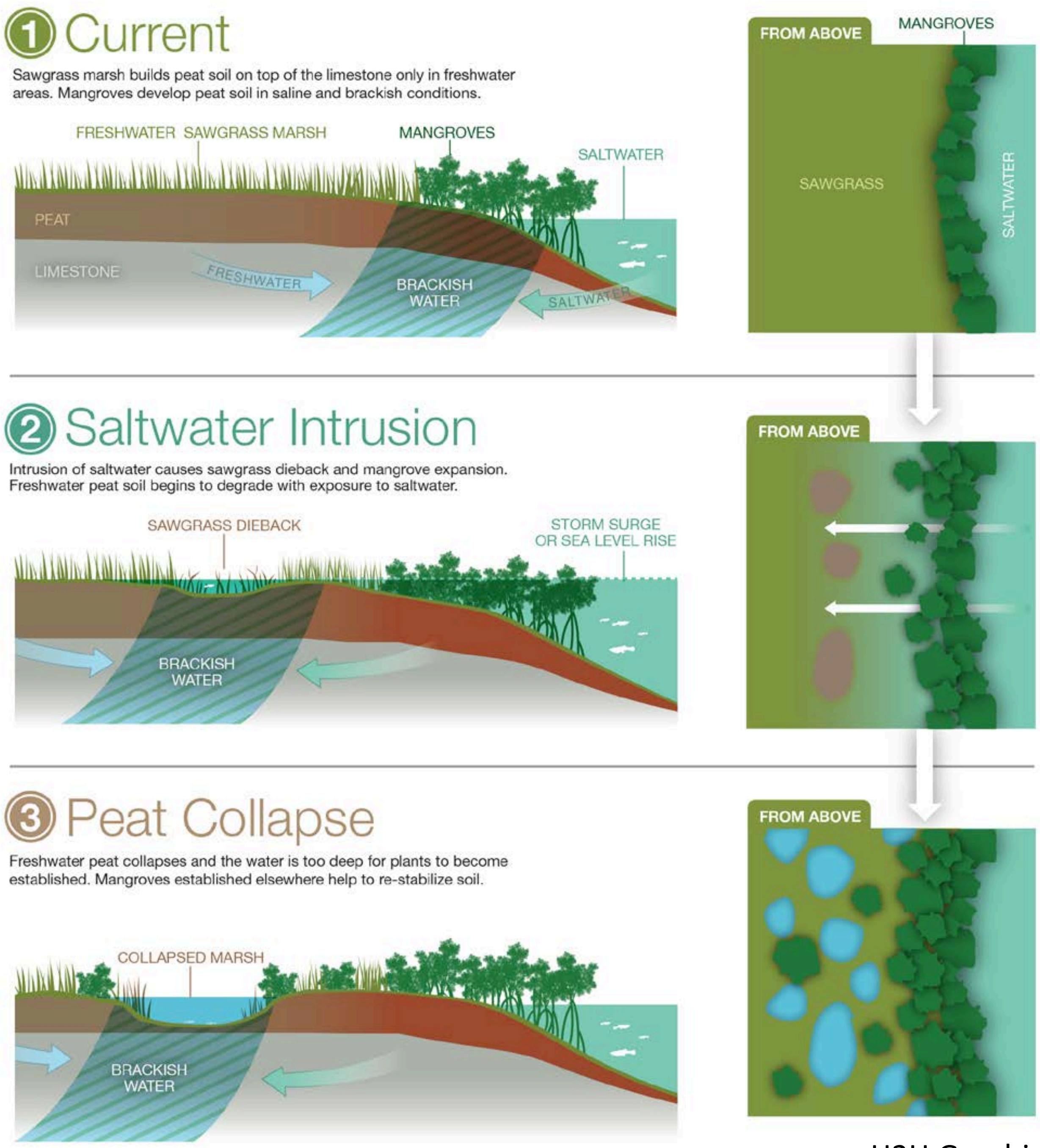


Historic and current flow of the Kissimmee, Okeechobee, Everglades watershed.

Graphic: U.S. Army Corps of Engineers, Jacksonville District

What potentially drives peat collapse?

1. Saltwater



H2H Graphics and Steve Davis

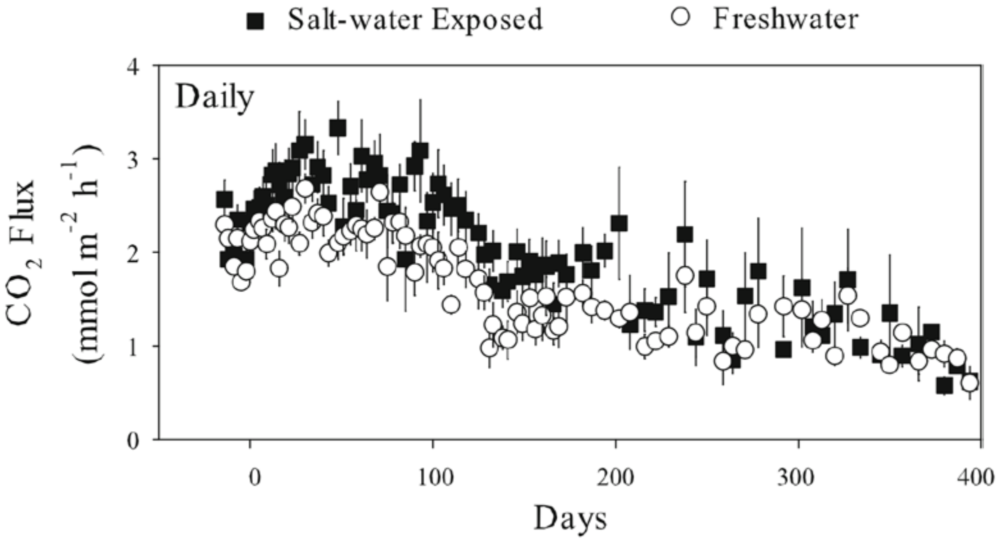
C responses to saltwater intrusion

R

Biogeochemistry (2011) 102:135–151
DOI 10.1007/s10533-010-9427-4

Accelerated microbial organic matter mineralization following salt-water intrusion into tidal freshwater marsh soils

Nathaniel B. Weston · Melanie A. Vile ·
Scott C. Neubauer · David J. Velinsky

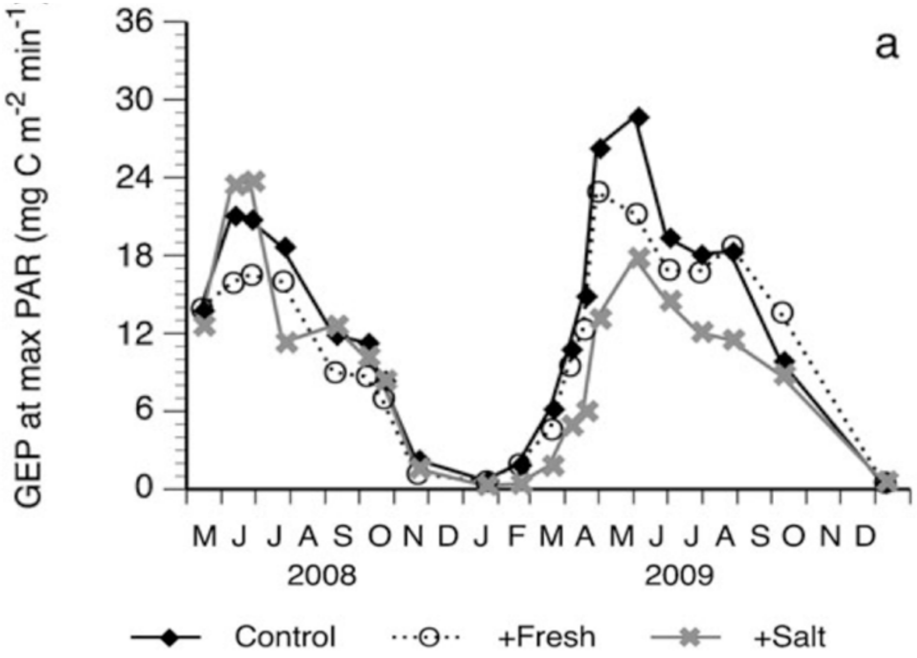


Estuaries and Coasts
DOI 10.1007/s12237-011-9455-x

Ecosystem Responses of a Tidal Freshwater Marsh Experiencing Saltwater Intrusion and Altered Hydrology

Scott C. Neubauer

GPP



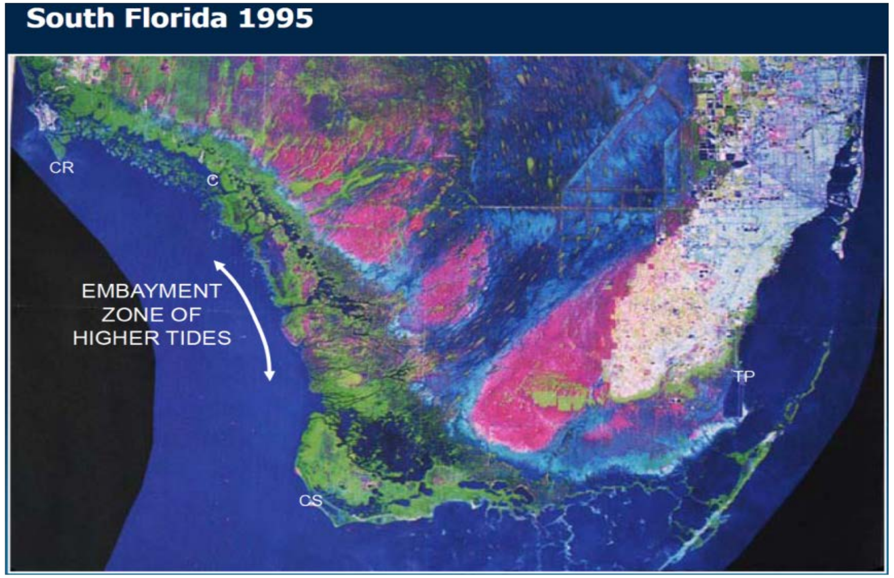
Stressors associated with sea level rise such as elevated salinity and increased inundation can change ecosystem C cycling

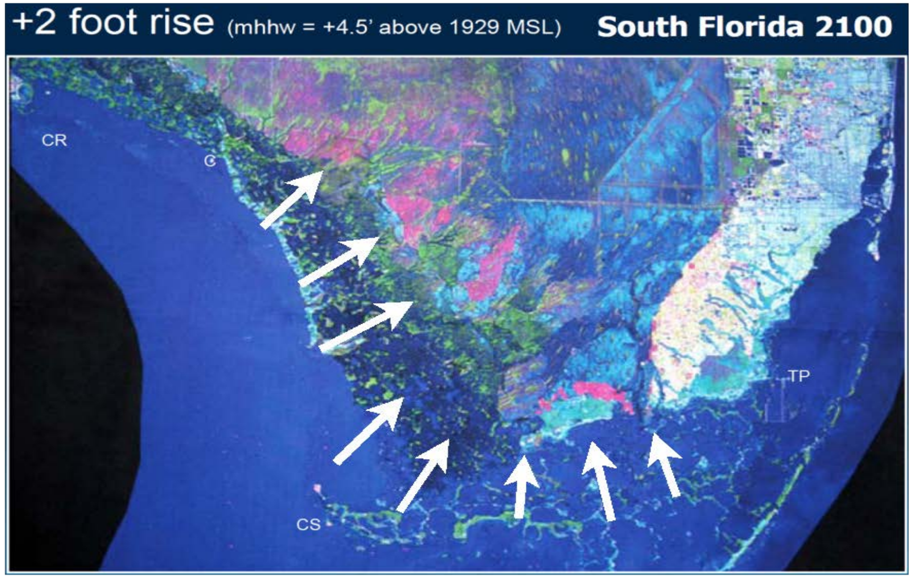
What potentially drives peat collapse?

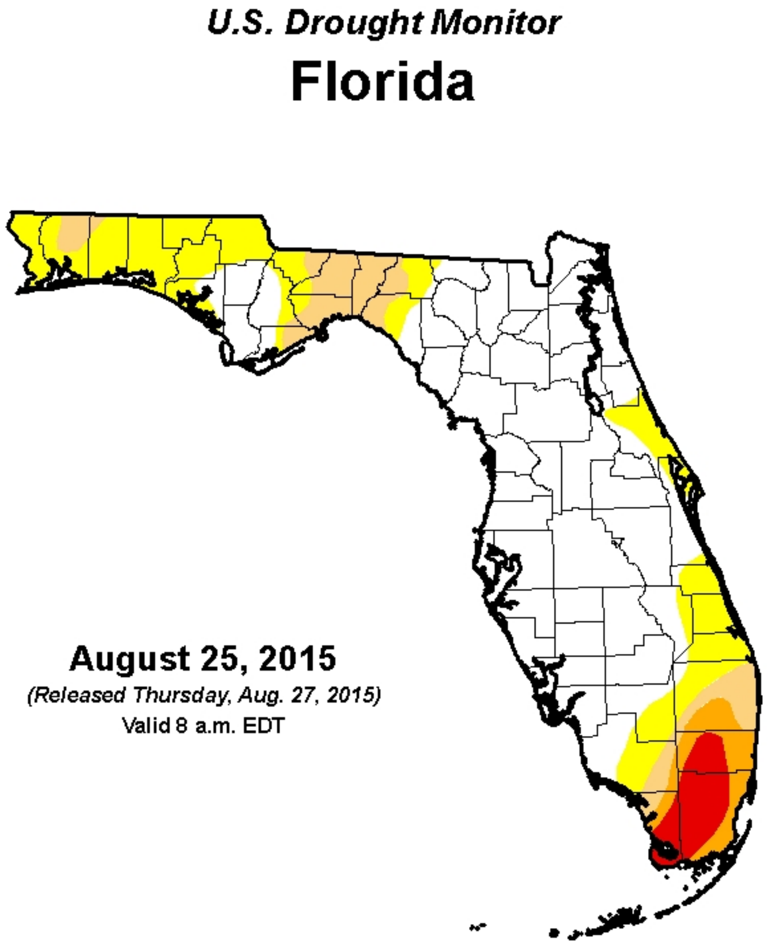
1. Saltwater
2. Nutrients (P)
3. Hydrology (Inundation and drought)

Inundation

Drought







Hal Wanless, Univ. of Miami

The Experiments

Freshwater

1. Field
   - Salinity (0 → 3 ppt)
2. Mesocosm
   - Salinity (0 → 8 ppt)
   - P (~2 x ambient)

Brackish

3. Field
   - Salinity (10 → 15 ppt)
4. Mesocosm
   - Salinity (10 → 20 ppt)
   - Inundation
5. Mesocosm
   - Salinity (10 → 20 ppt)
   - Drought

The Experiments

Freshwater

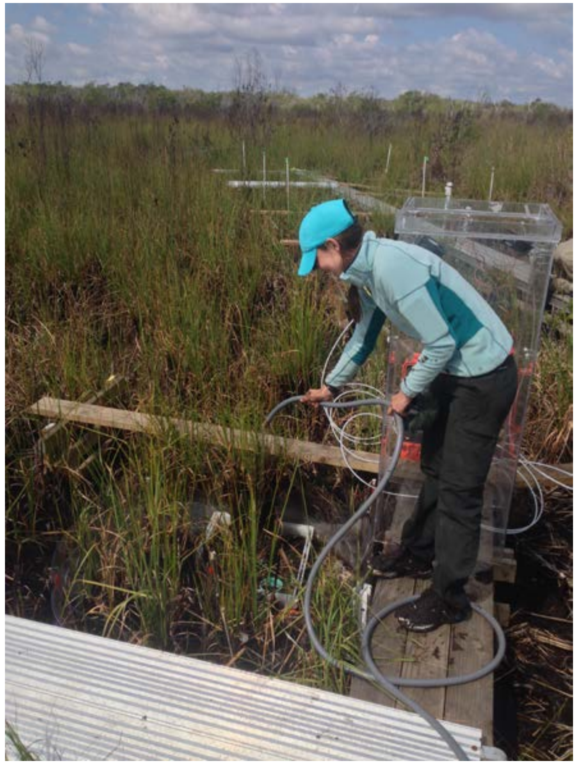
1. Field
   - Salinity (0 → 3 ppt)
2. Mesocosm
   - Salinity (0 → 8 ppt)
   - P (~2 x ambient)

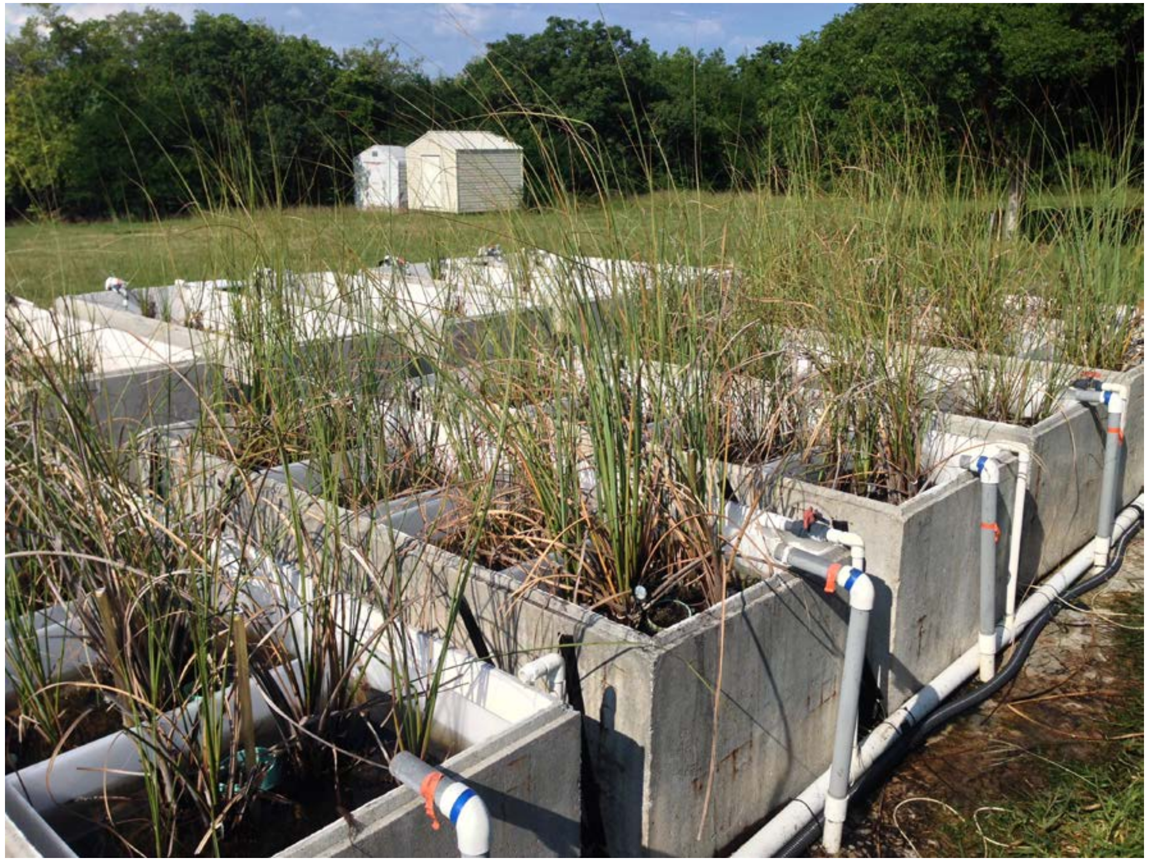
Brackish

3. Field
   - Salinity (10 → 15 ppt)
4. Mesocosm
   - Salinity (10 → 20 ppt)
   - Inundation
5. Mesocosm
   - Salinity (10 → 20 ppt)
   - Drought

Field

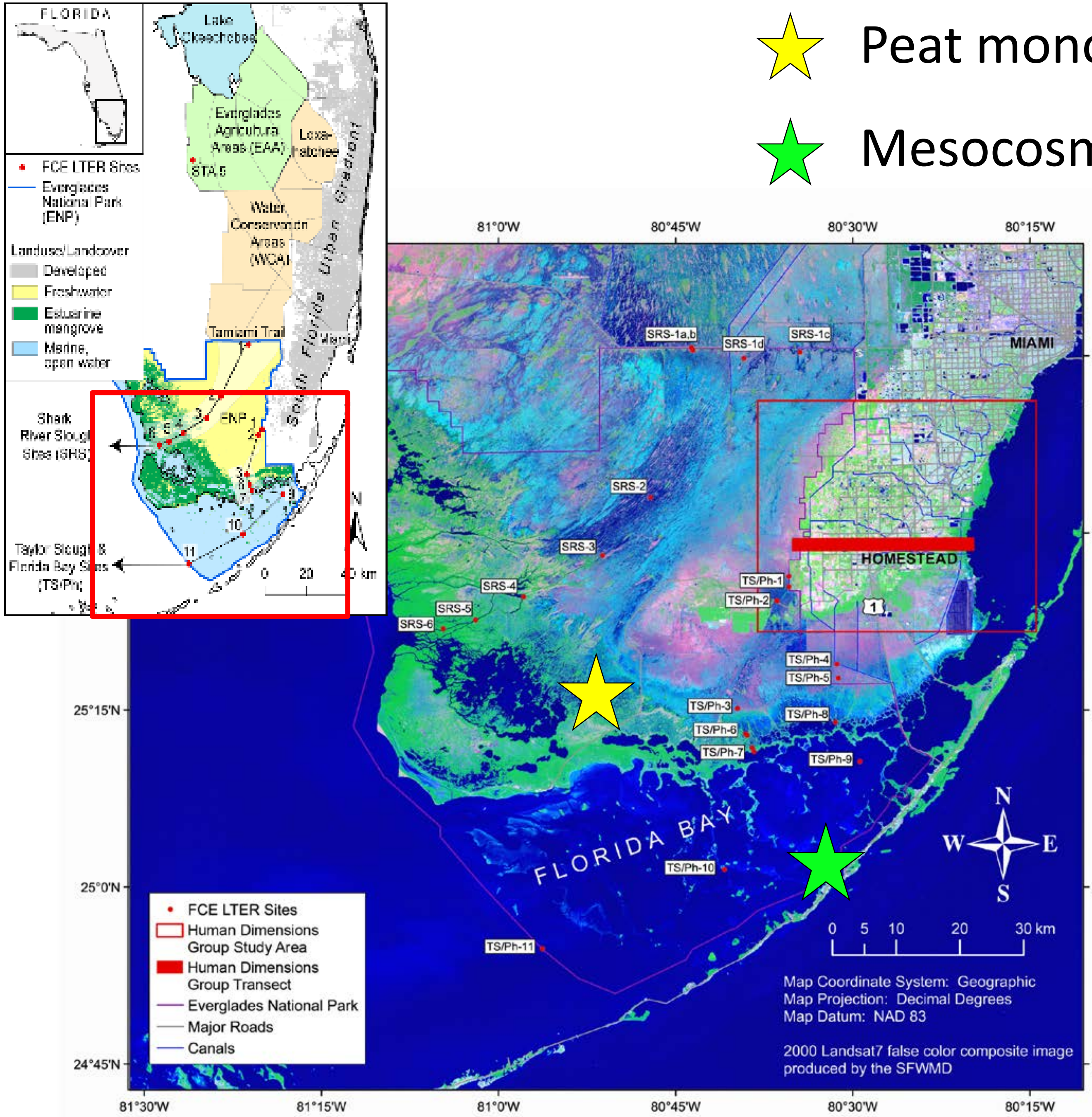
Mesocosm



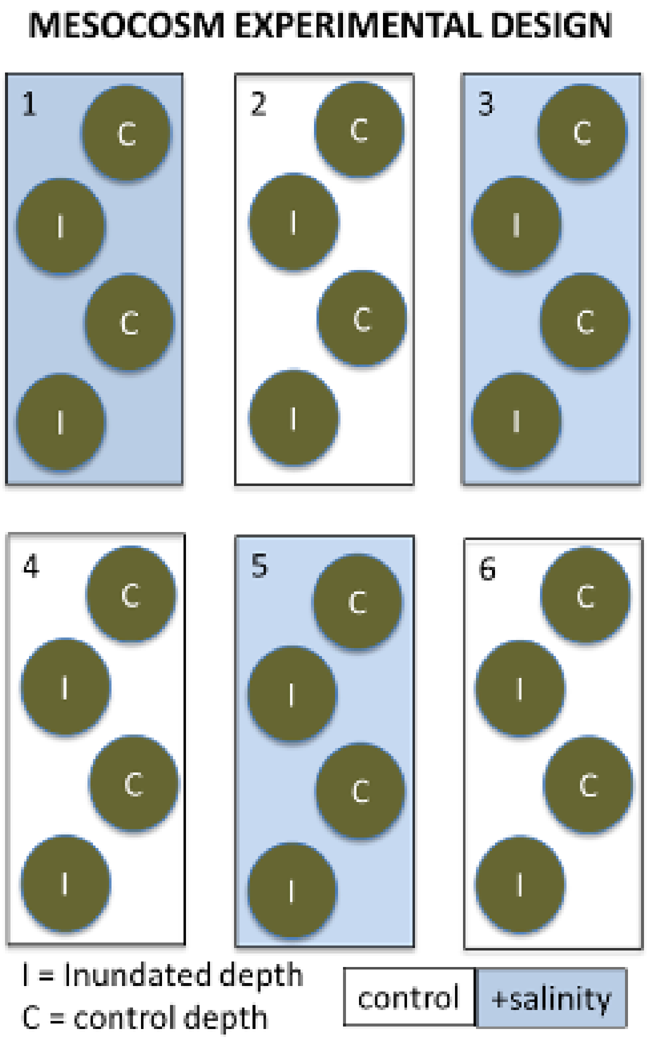


Peat monolith collection site

Mesocosm Facilities



Methods



Date	Control water level	Drought water level
Sep 2016	Submerged	Submerged
Oct 2016	Submerged	Submerged
Nov 2016	Submerged	Submerged
Dec 2016	Submerged	Submerged
Jan 2017	Submerged	At Soil Surface
Feb 2017	Submerged	-10 cm
Mar 2017	Submerged	-20 cm
Apr 2017	Submerged	-20 cm
May 2017	Submerged	-20 cm
Jun 2017	Submerged	-20 cm
Jul 2017	Submerged	-10 cm
Aug 2017	Submerged	Submerged
Sep 2017	Submerged	Submerged

- Split-Plot design with repeated measures
- 24 **sawgrass-peat** cores collected from **brackish marsh**
  - Treatments of Salinity
    - **Ambient (~10 ppt)**
    - **Elevated (~20 ppt)**
  - Inundation
    - **Submerged** (Entire monolith below water)
    - **Drought** (Variable water level)
  - 12-month experimental period (Oct 2016 to Sep 2017)

Methods

Monthly

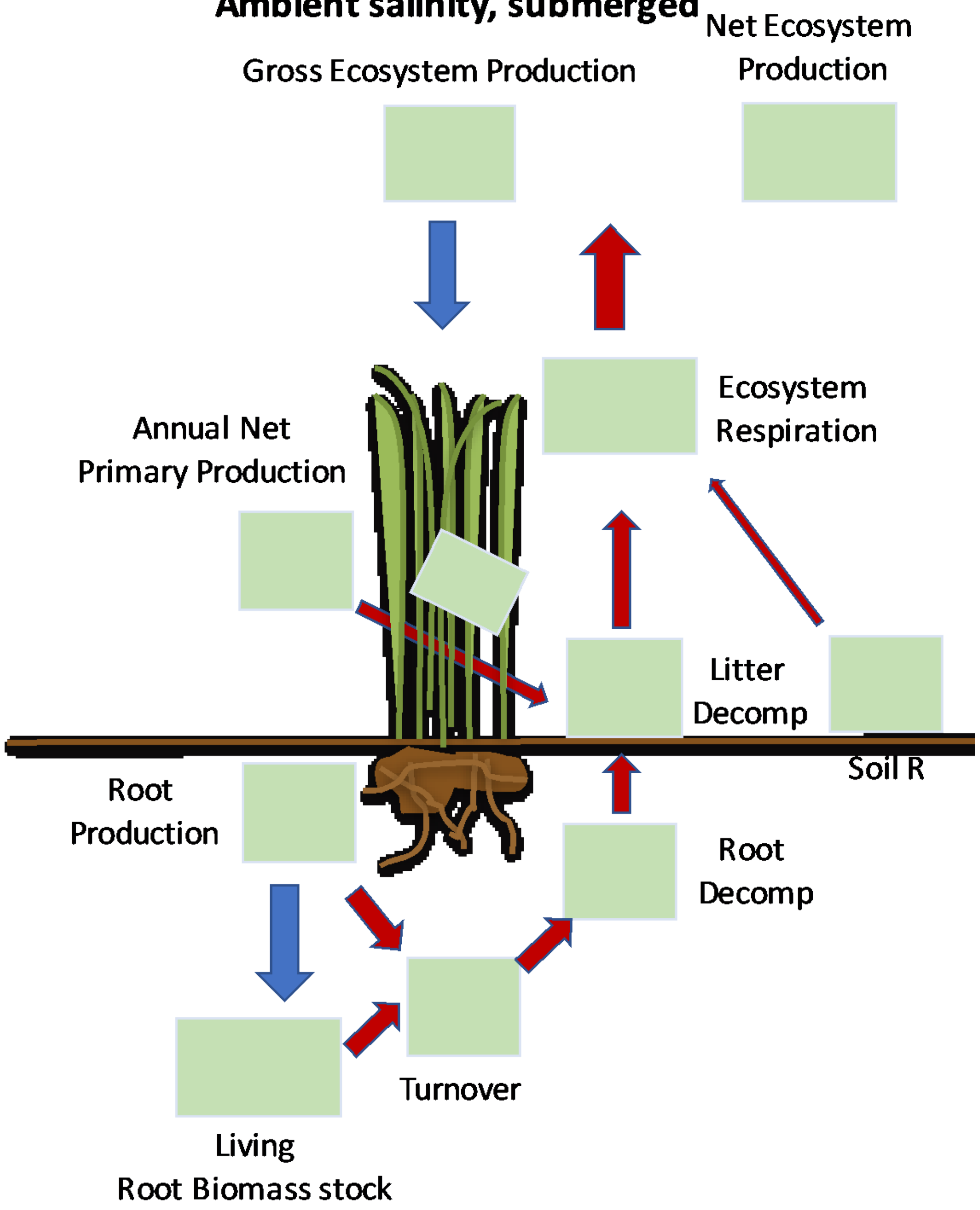
- Soil CO_2 flux
- Ecosystem CO_2 flux
- Elevation change
- NPP

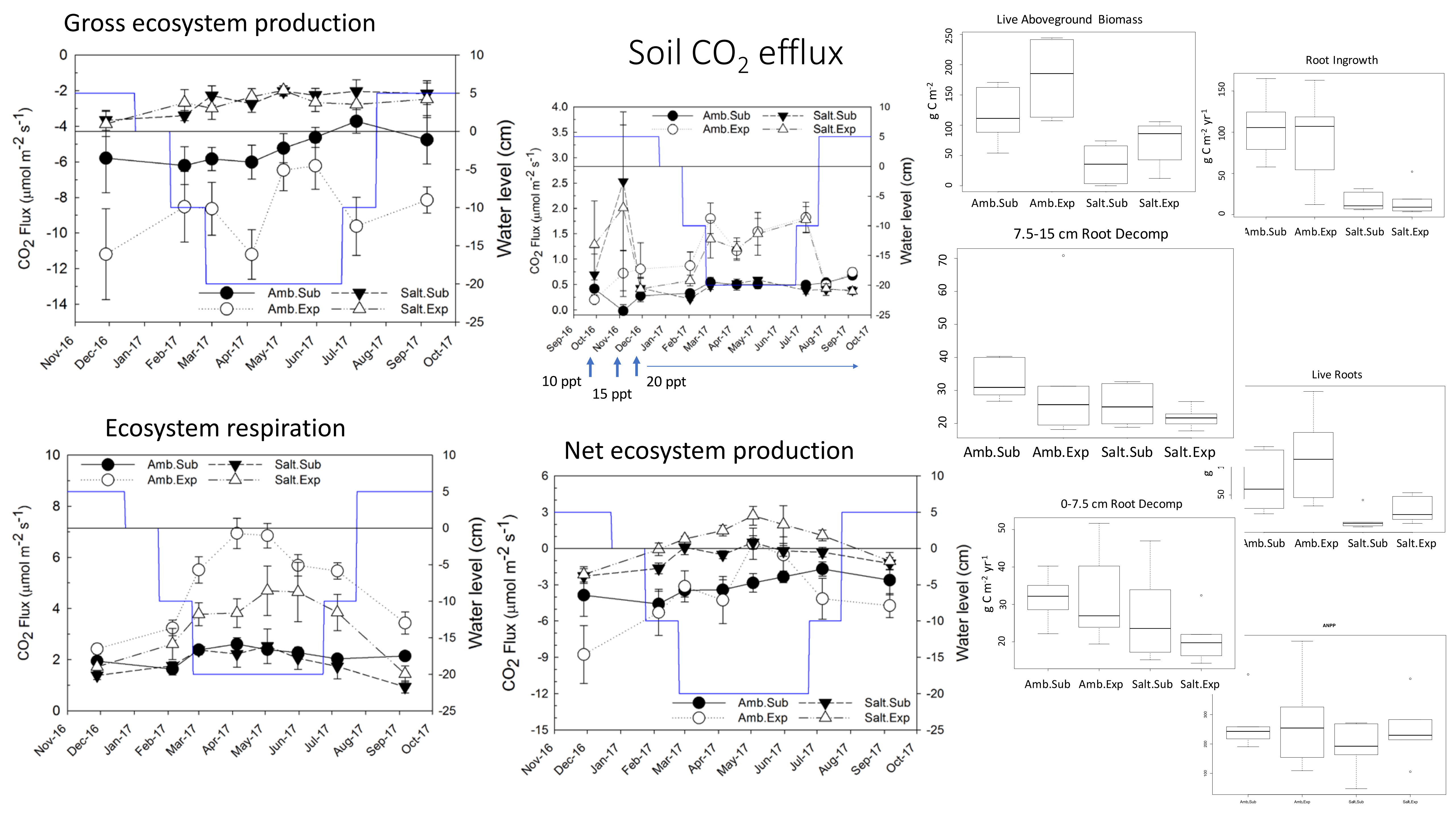
One-time

- Aboveground biomass
- Root biomass, growth
- Decomposition

- Statistics
  - Linear mixed models (R; nlme)

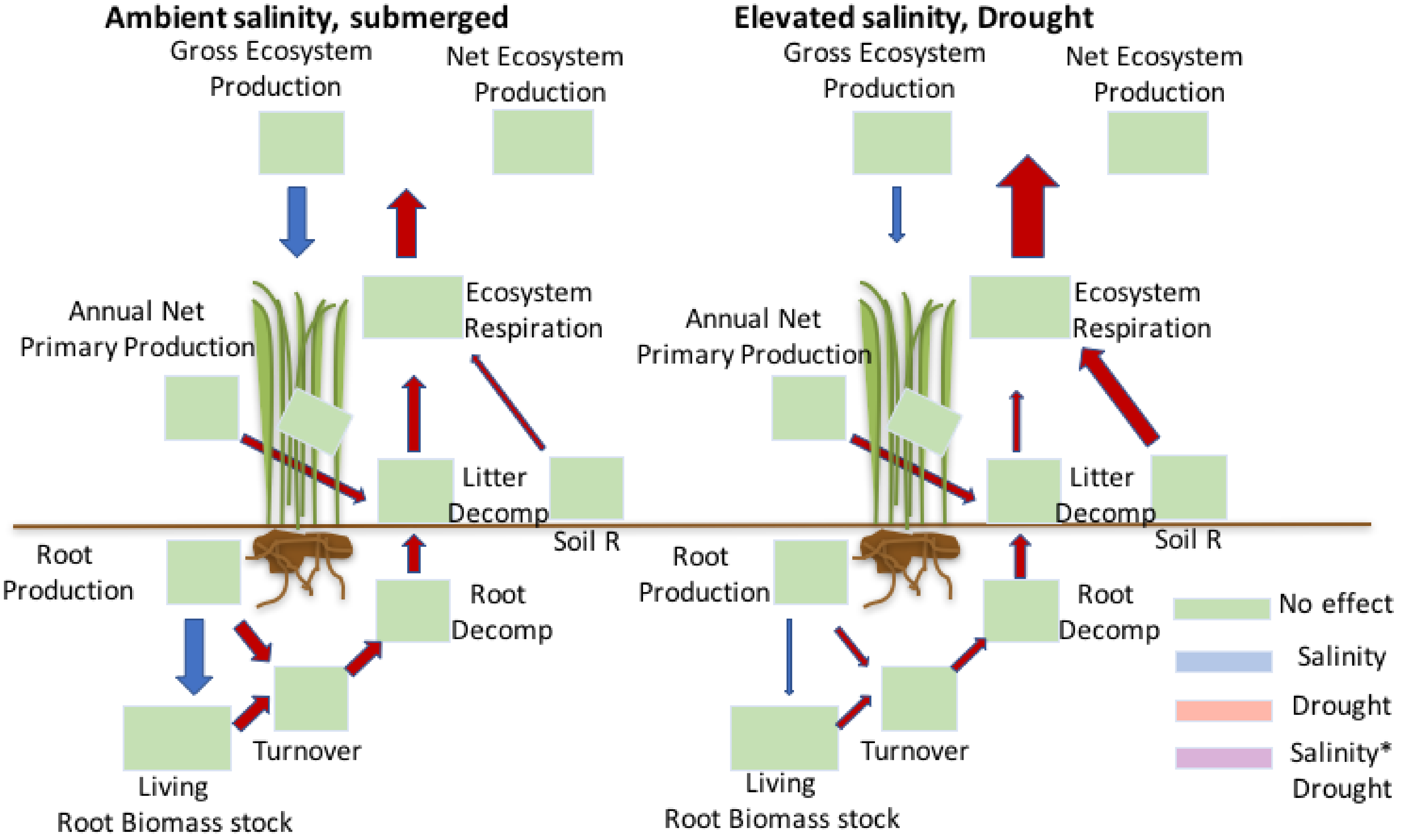
Ambient salinity, submerged





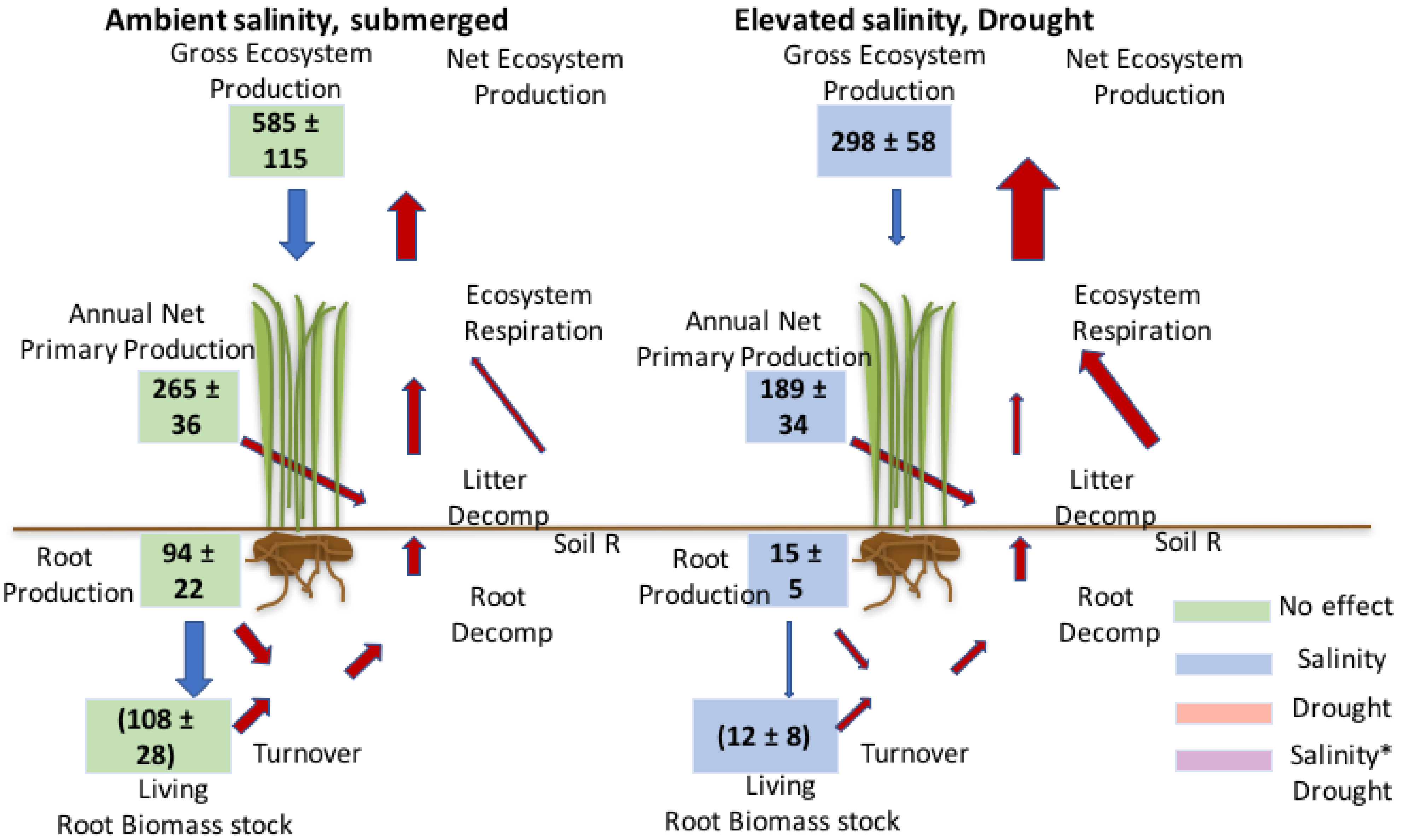
Gross ecosystem production
CO2 Flux (µmol m-2 s-1)
Water level (cm)
Amb.Sub
Amb.Exp
Salt.Sub
Salt.Exp
Nov-16 Dec-16 Jan-17 Feb-17 Mar-17 Apr-17 May-17 Jun-17 Jul-17 Aug-17 Sep-17 Oct-17
Soil CO2 efflux
Sep-16 Oct-16 Nov-16 Dec-16 Jan-17 Feb-17 Mar-17 Apr-17 May-17 Jun-17 Jul-17 Aug-17 Sep-17 Oct-17
10 ppt
15 ppt
20 ppt
Ecosystem respiration
Net ecosystem production
Live Aboveground Biomass
g C m-2
Root Ingrowth
g C m-2 yr-1
7.5-15 cm Root Decomp
Live Roots
0-7.5 cm Root Decomp
ANPP

Net Ecosystem Carbon Balance (g C m^{-2} yr^{-1})



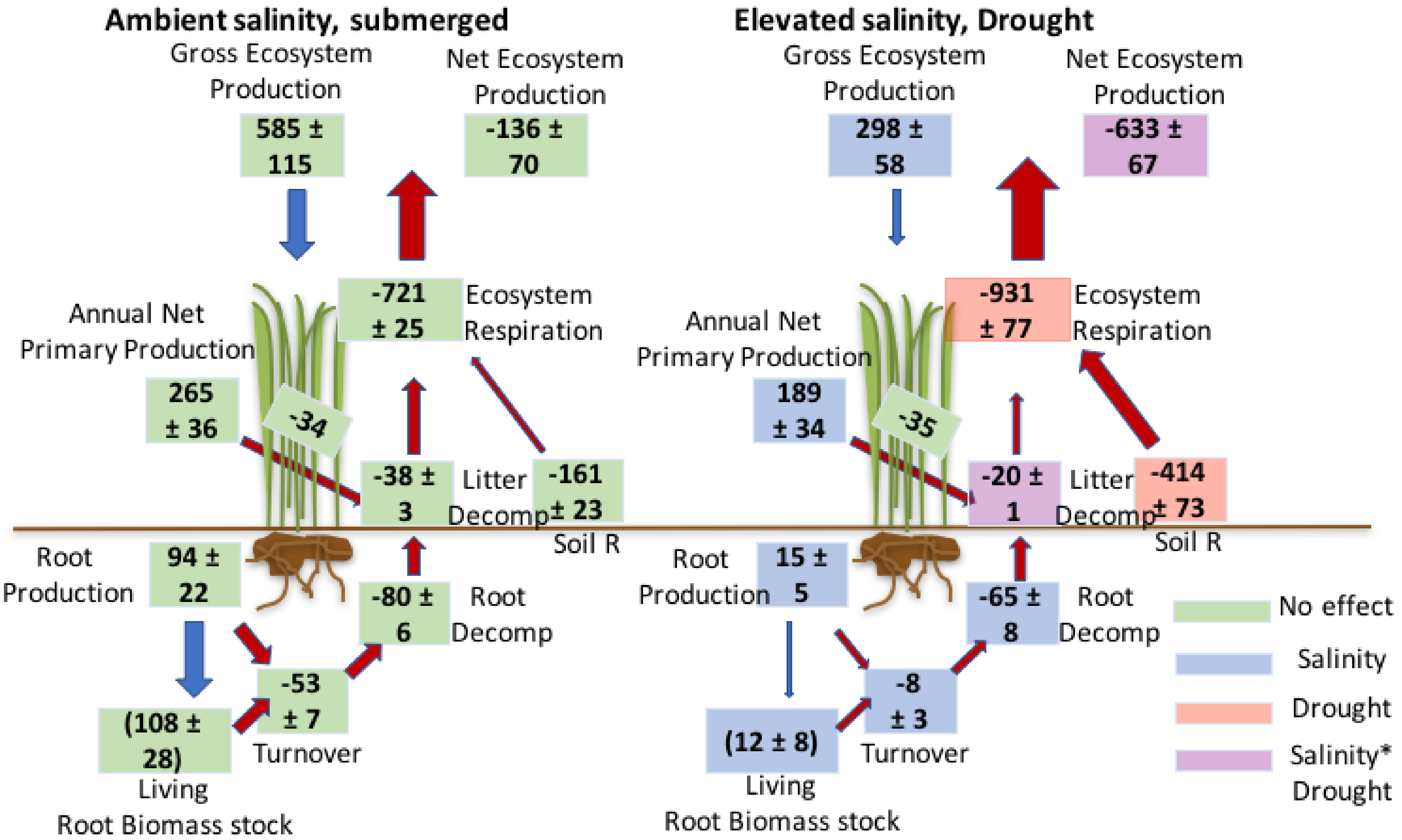
Arrows *marginally* drawn to scale

Net Ecosystem Carbon Balance (g C m^{-2} yr^{-1})



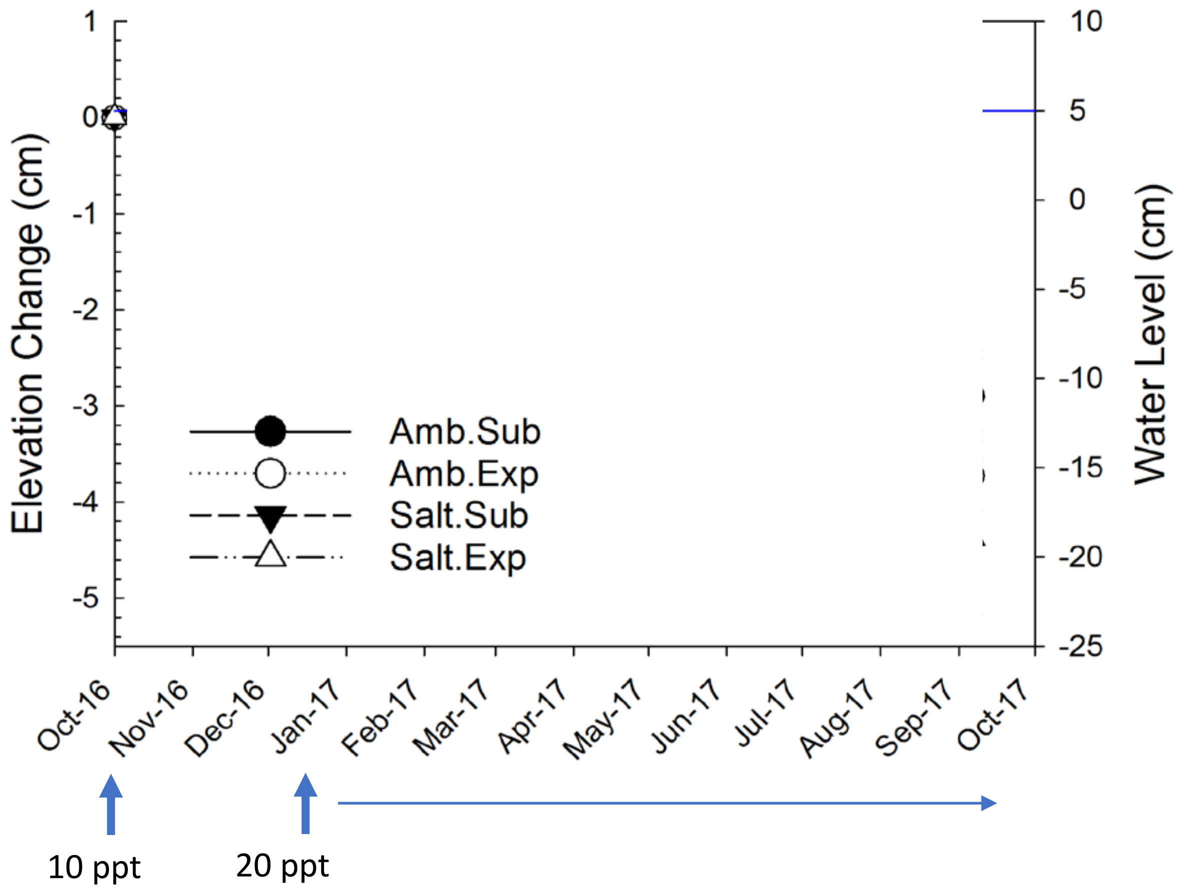
Arrows *marginally* drawn to scale

Net Ecosystem Carbon Balance (g C m^{-2} yr^{-1})



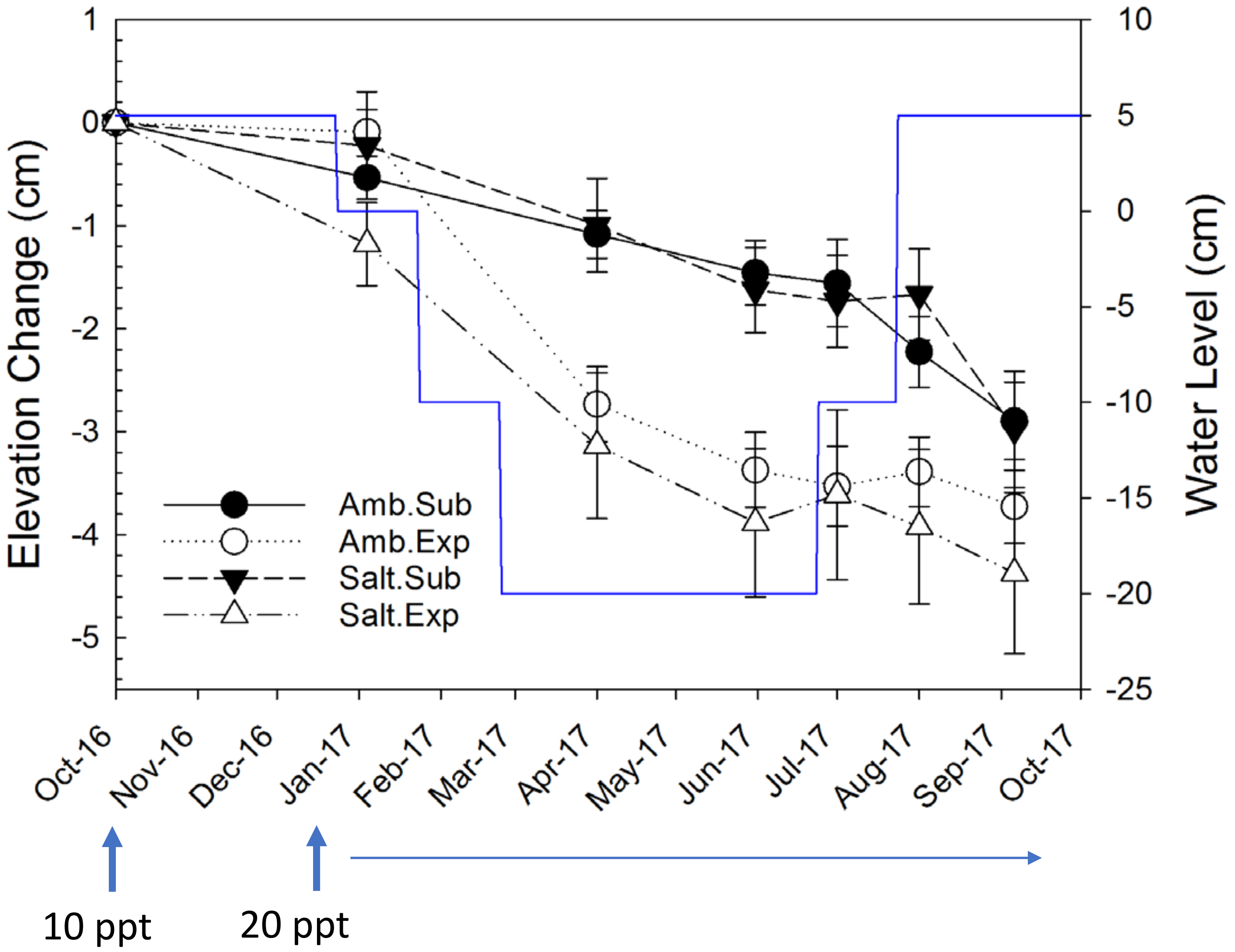
Arrows *marginally* drawn to scale

Elevation Change



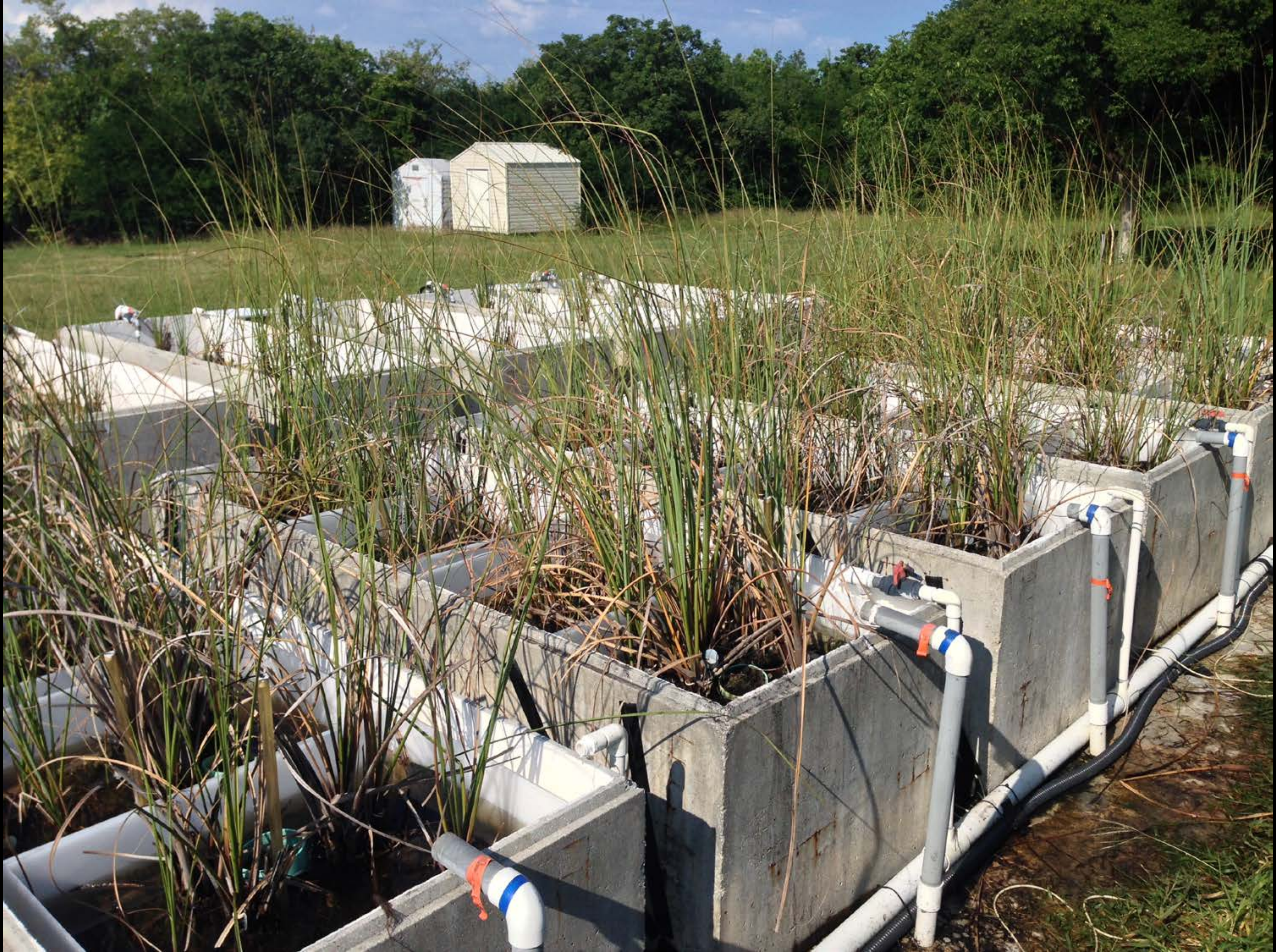
Amb = Ambient Salinity
Salt = Elevated Salinity
Sub = Submerged
Exp = Drought treatment

Elevation Change

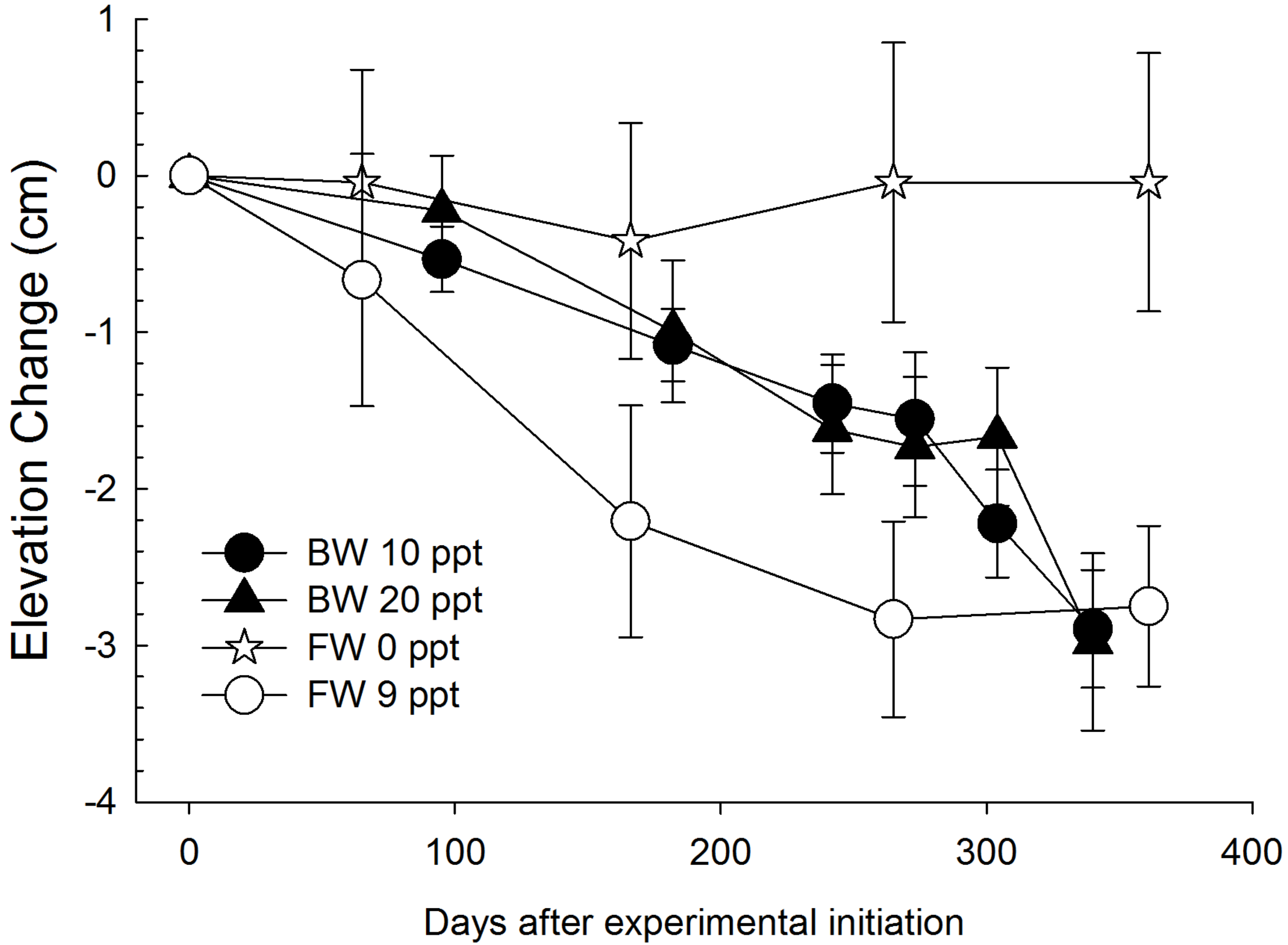


	p value
Salinity	0.602
Inundation	**0.001**
Salinity*Inundation	0.471

Amb = Ambient Salinity
Salt = Elevated Salinity
Sub = Submerged
Exp = Drought treatment



Elevation Change



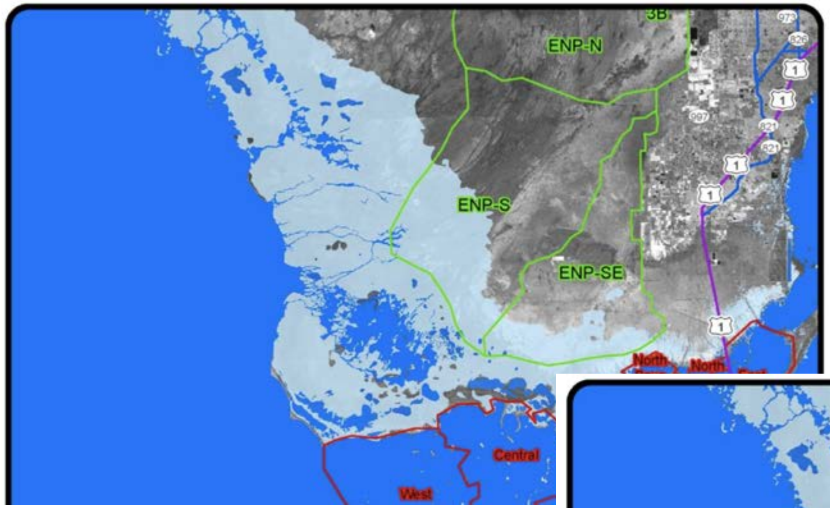
What drives peat collapse?*

- Saltwater
  - Decreases root growth and increases root death
  - At a certain level, begins to decrease GEP and shift the marsh from a net C sink to source
- Hydrology
  - Seasonal dry-down can accelerate elevation loss

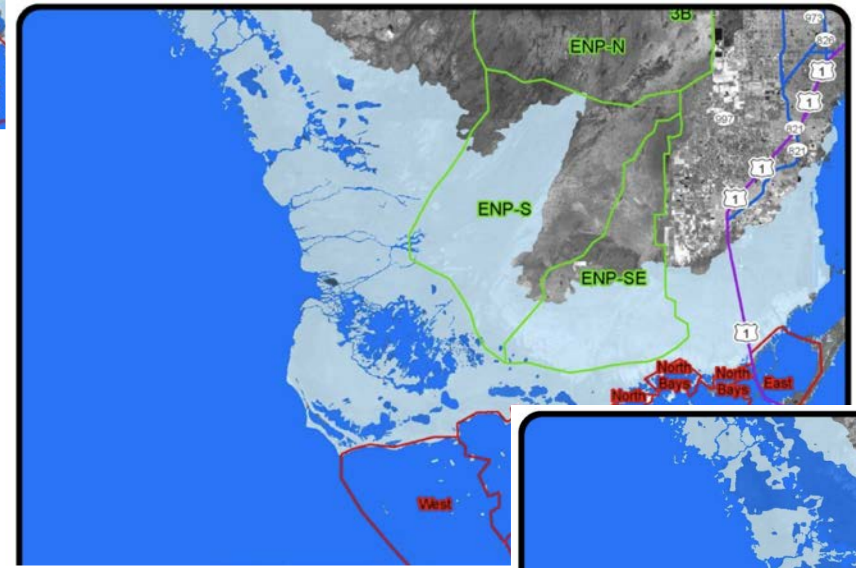
*What we know so far

Implications for peat collapse

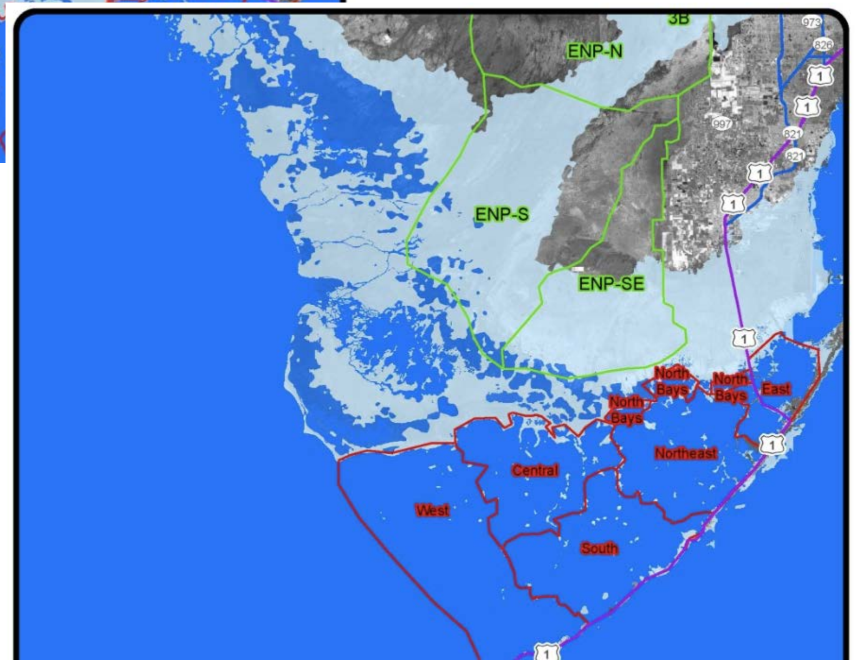
Areas of marine water influence in 50 years under different scenarios



1 foot, no peat loss



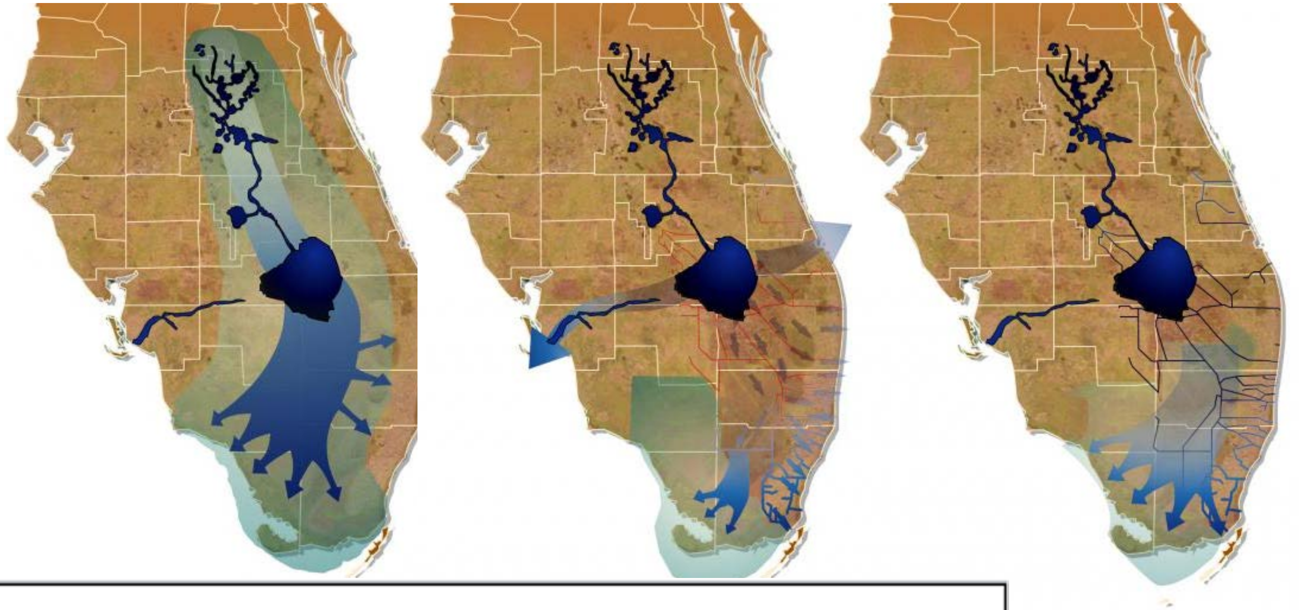
1 foot, peat loss

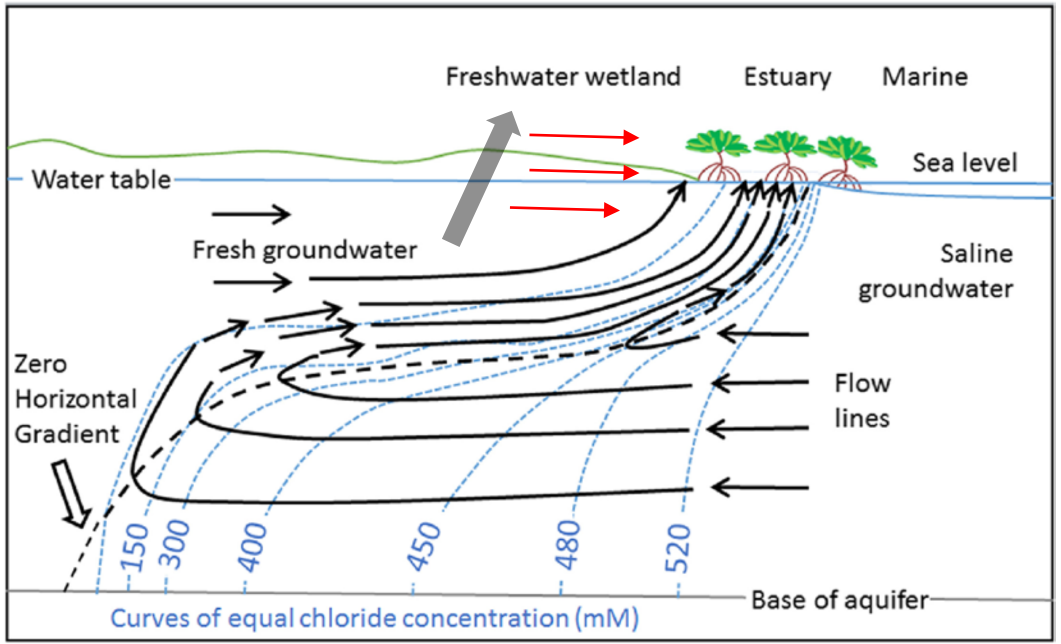


2 feet, peat loss

USACE 2014

What can be done?





- Restoration can push back saltwater intrusion
- Restoration means more water cover the marsh for a longer period of time, preventing extended dry-downs and acceleration of peat collapse

Flower et al. 2017

Acknowledgements

- All field help
  - Laura Bauman
  - Ryan Stolee
- NSF Doctoral Dissertation Improvement Grant
- FIU Dissertation Year Fellowship
- NSF grant #DEB-1701763

FIU
FLORIDA INTERNATIONAL UNIVERSITY

Sea Grant
Florida

FCE LTER

EVERGLADES FOUNDATION

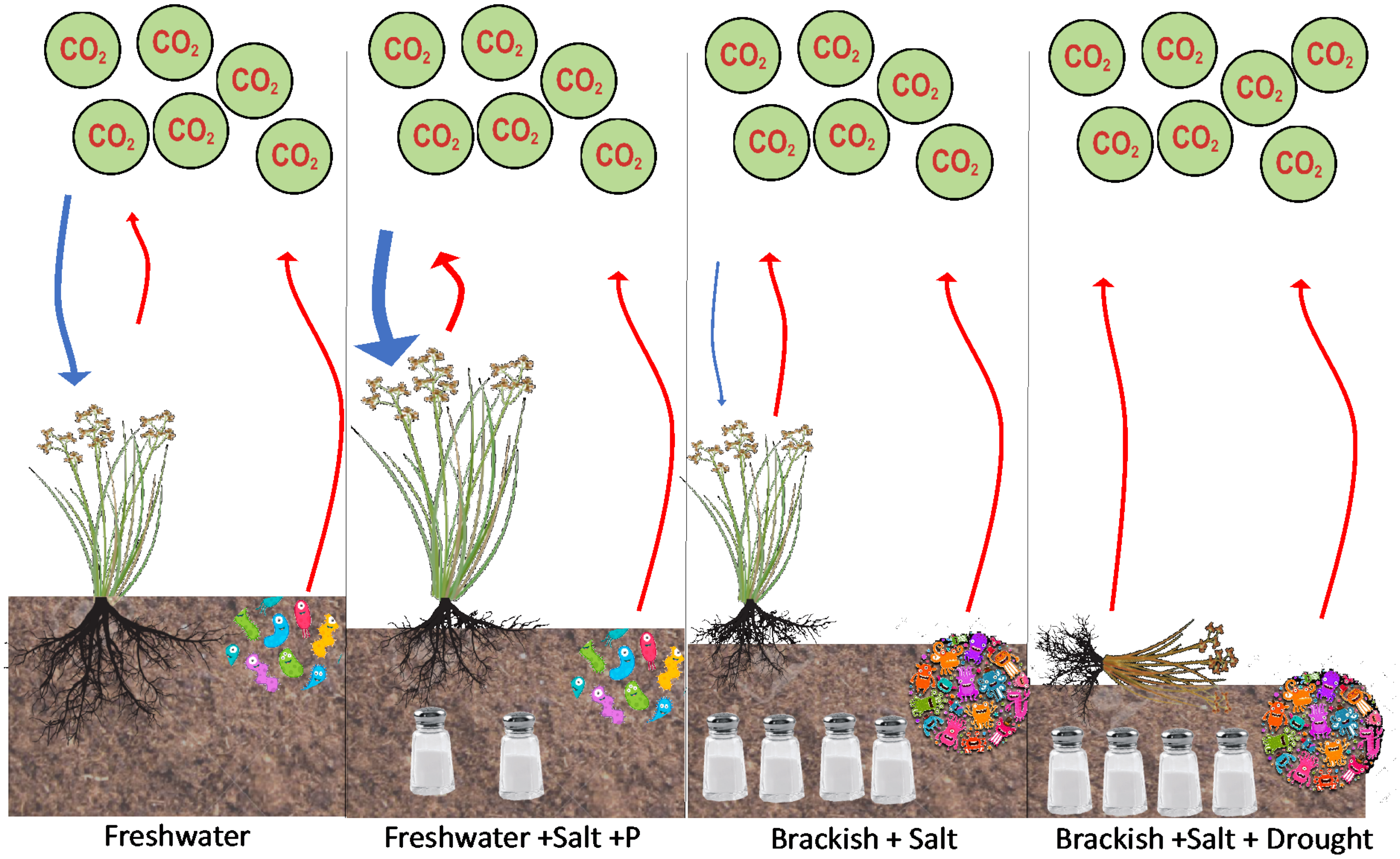
NSF

NATIONAL PARK SERVICE

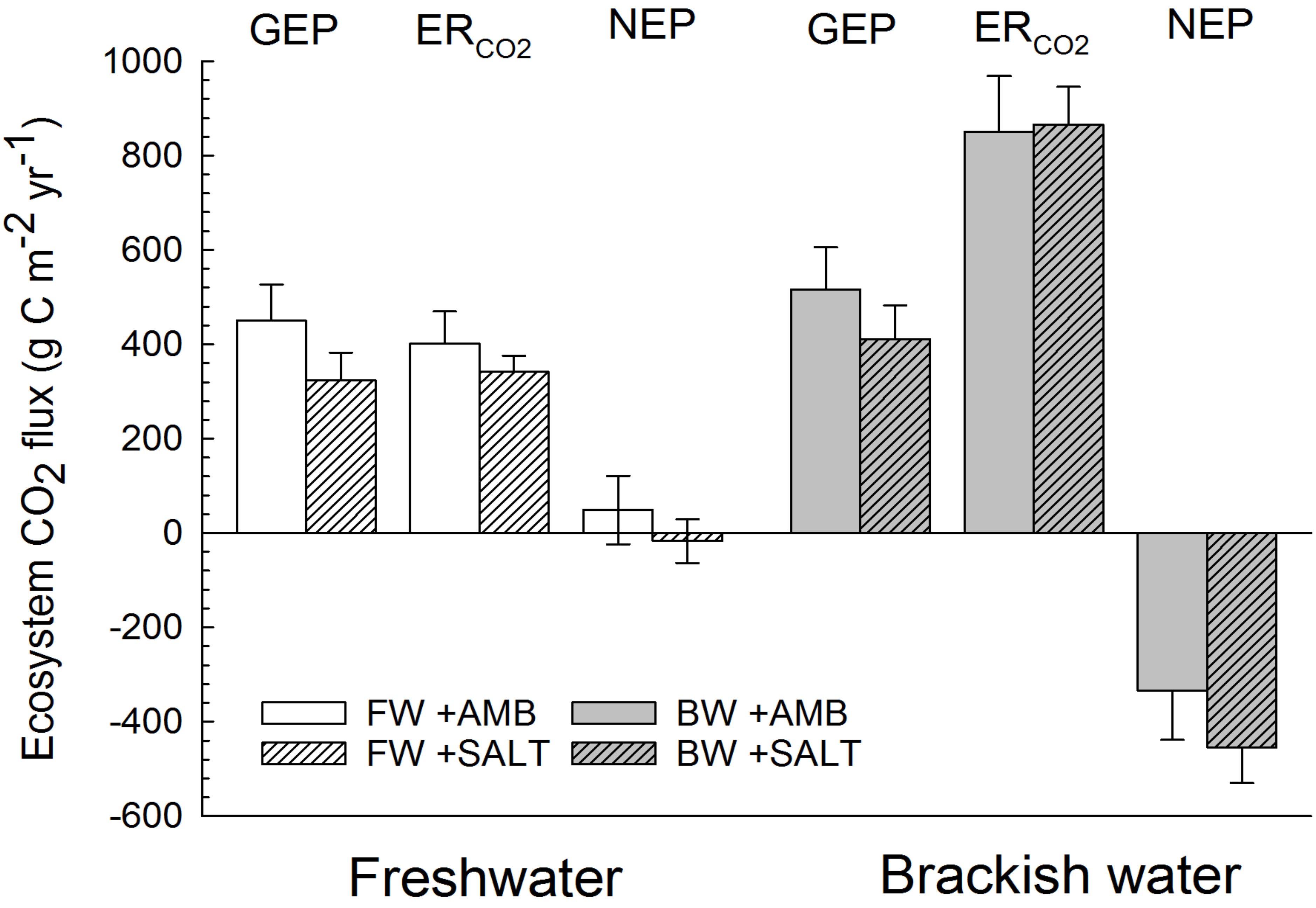
SOUTH FLORIDA WATER MANAGEMENT DISTRICT
PROTECTOR OF THE EVERGLADES SINCE 1949
sfwmd.gov

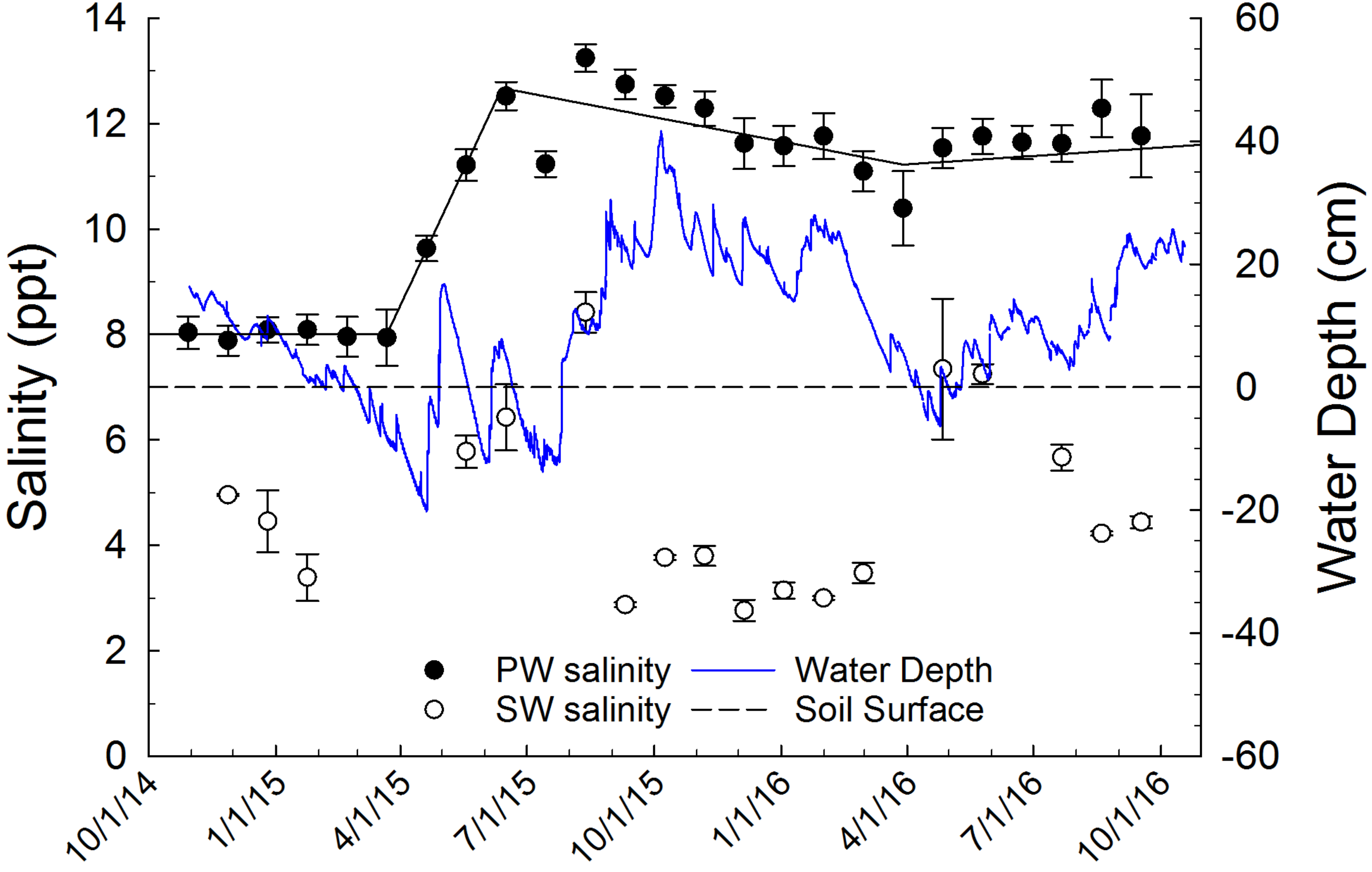
Questions??

Conclusion



CO2
Freshwater
Freshwater +Salt +P
Brackish + Salt
Brackish +Salt + Drought

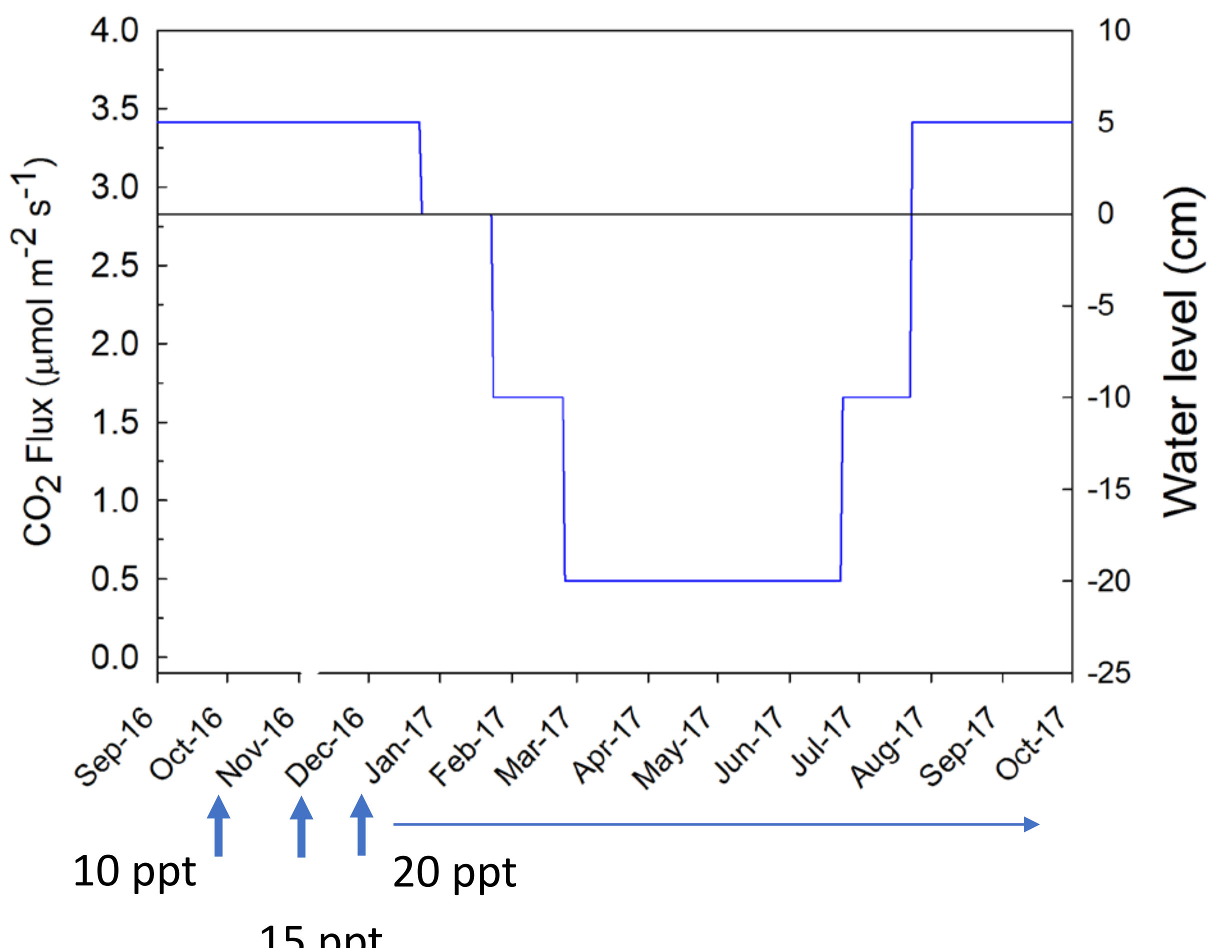

GEP
ER$_{CO2}$
NEP
GEP
ER$_{CO2}$
NEP
1000
800
600
400
200
0
-200
-400
-600
Ecosystem CO_2 flux (g C m^{-2} yr^{-1})
FW +AMB
FW +SALT
BW +AMB
BW +SALT
Freshwater
Brackish water



Salinity (ppt)
Water Depth (cm)
PW salinity
SW salinity
Water Depth
Soil Surface
0
2
4
6
8
10
12
14
60
40
20
0
-20
-40
-60
10/1/14
1/1/15
4/1/15
7/1/15
10/1/15
1/1/16
4/1/16
7/1/16
10/1/16

Soil CO_2 efflux

	p value
Salinity	
Inundation	
Salinity*Inundation	



Amb = Ambient Salinity

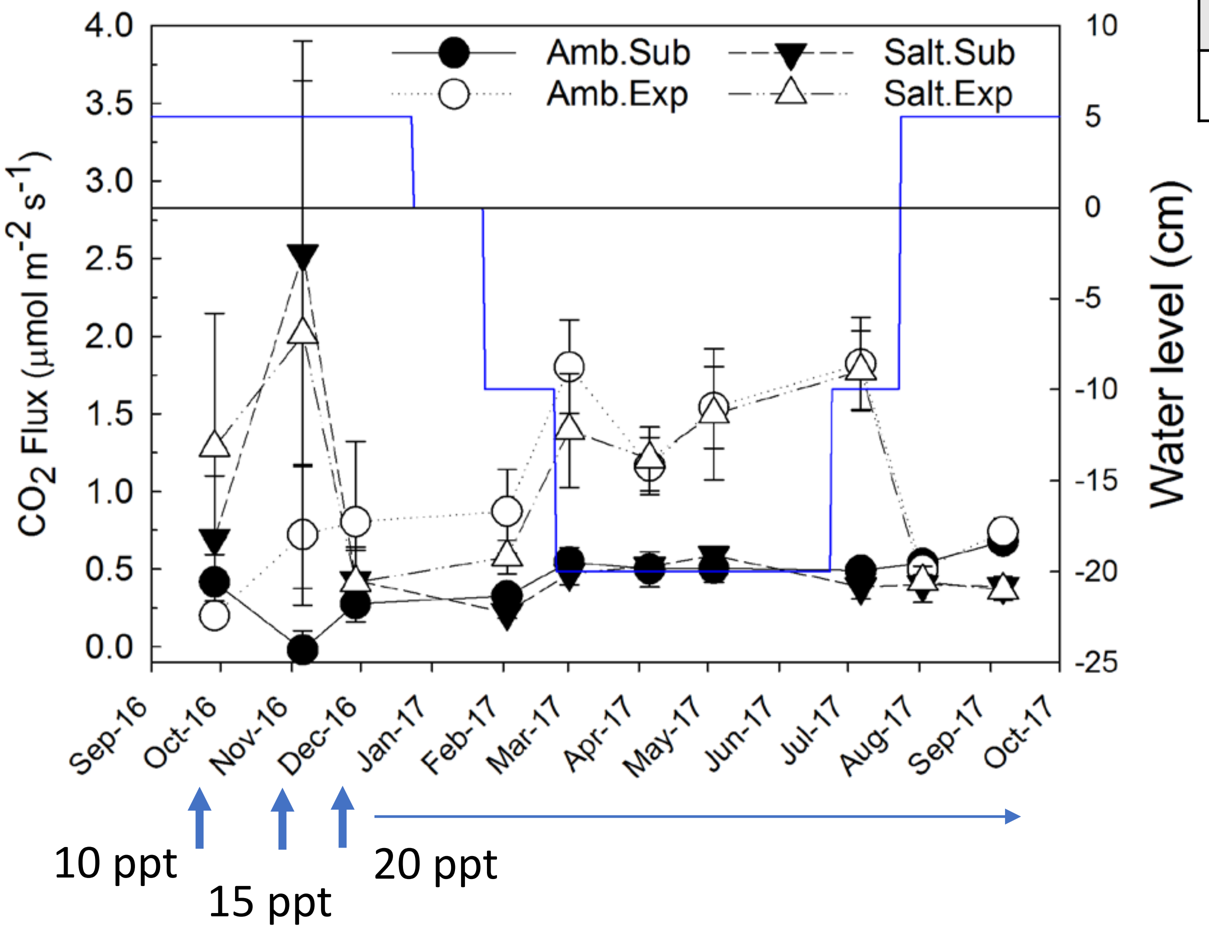
Salt = Elevated Salinity

Sub = Submerged

Exp = Drought treatment

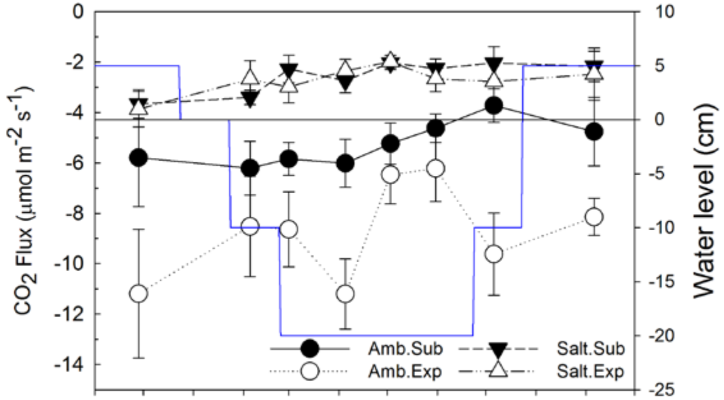
Soil CO_2 efflux

	p value
Salinity	0.374
Inundation	**0.019**
Salinity*Inundation	0.687



Amb = Ambient Salinity
Salt = Elevated Salinity
Sub = Submerged
Exp = Drought treatment

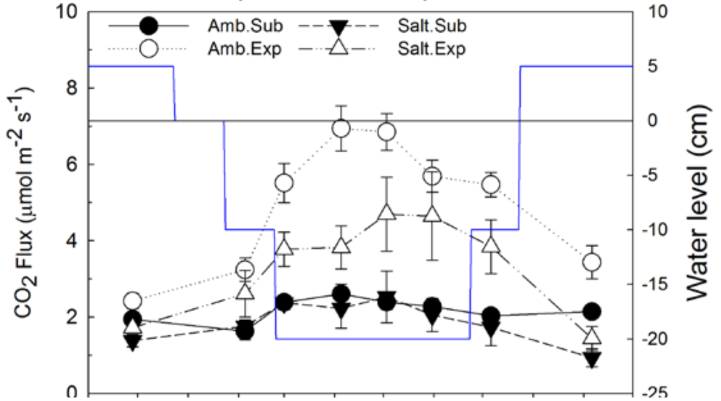
Gross ecosystem production



Salinity	<0.001
Inundation	0.062
Salinity*Inundation	0.090

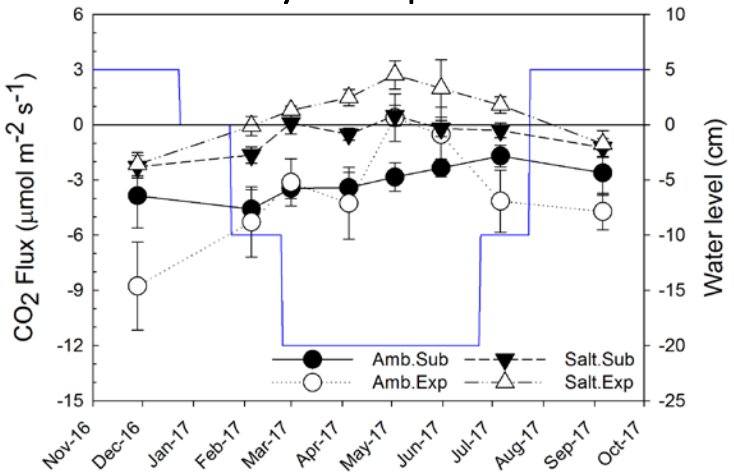
Amb = Ambient Salinity
Salt = Elevated Salinity
Sub = Submerged
Exp = Drought treatment

Ecosystem respiration



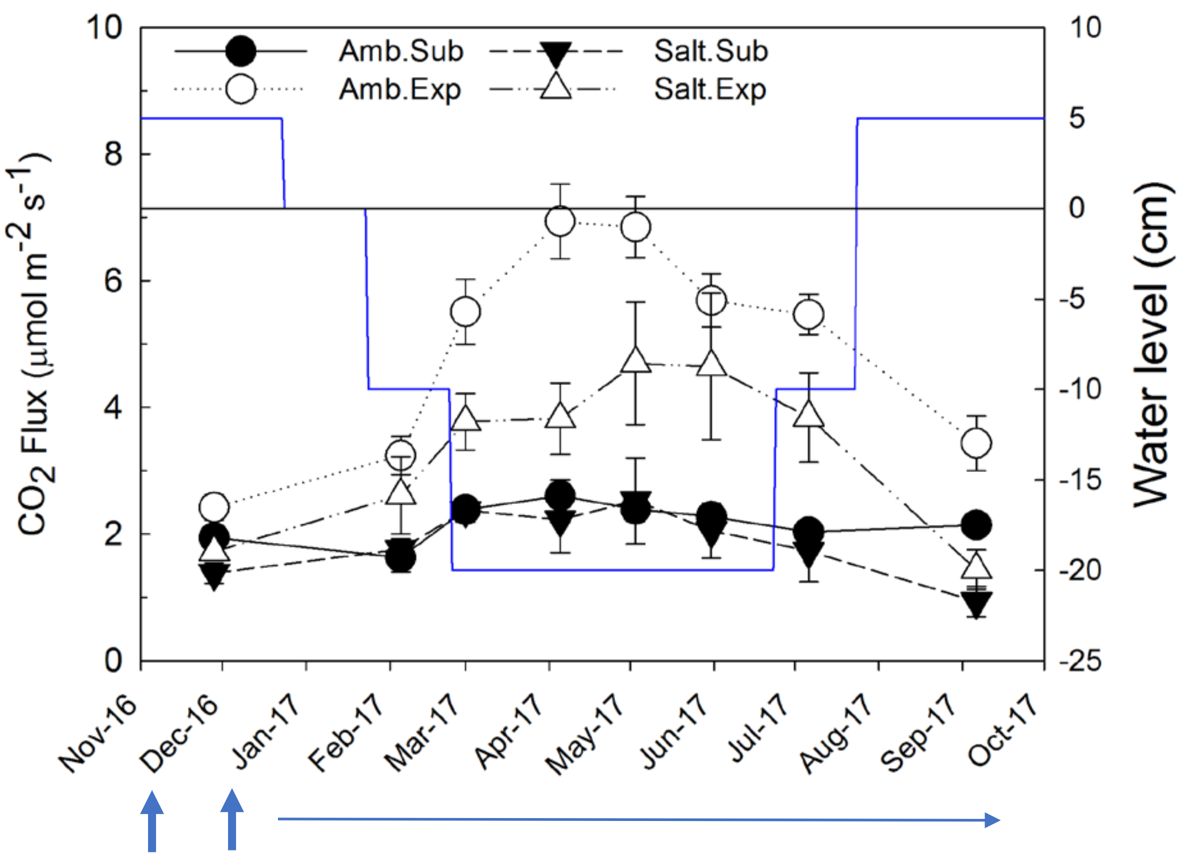
Salinity	0.020
Inundation	<0.001
Salinity*Inundation	0.077

Net ecosystem production



Salinity	0.002
Inundation	0.669
Salinity*Inundation	0.312

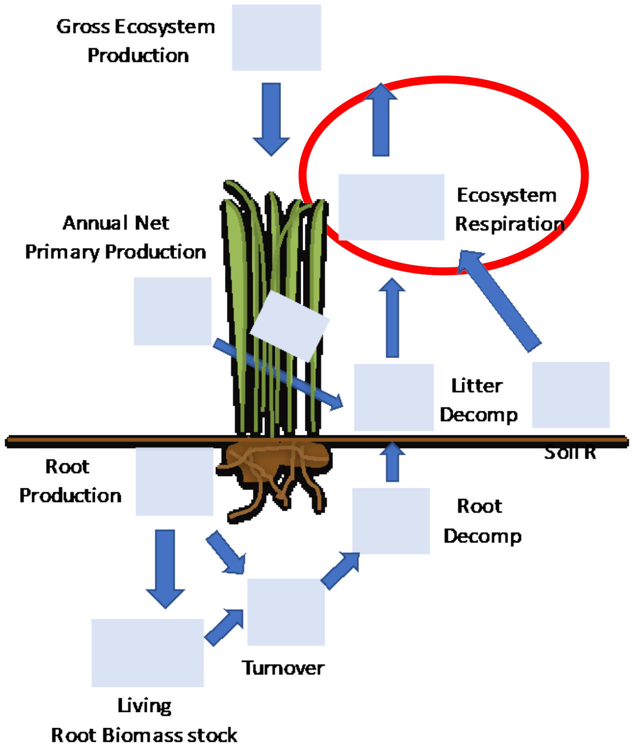
Ecosystem Respiration



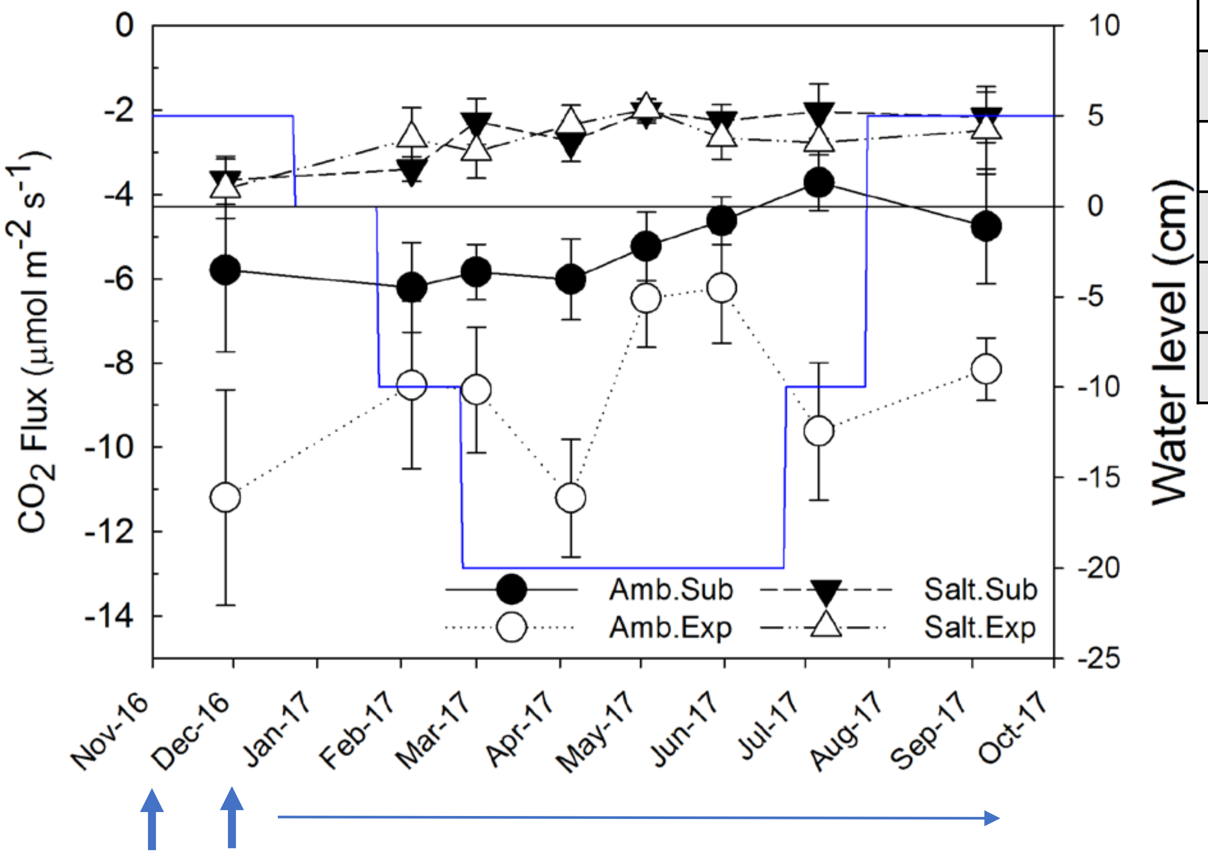
15 ppt 20 ppt

Amb = Ambient Salinity
Salt = Elevated Salinity
Sub = Submerged
Exp = Drought treatment

Salinity	**0.020**
Inundation	**<0.001**
Date	**<0.001**
Salinity*Inundation	0.077
Salinity*Date	**0.045**
Inundation*Date	**<0.001**
Salinity*Inundation*Date	0.084



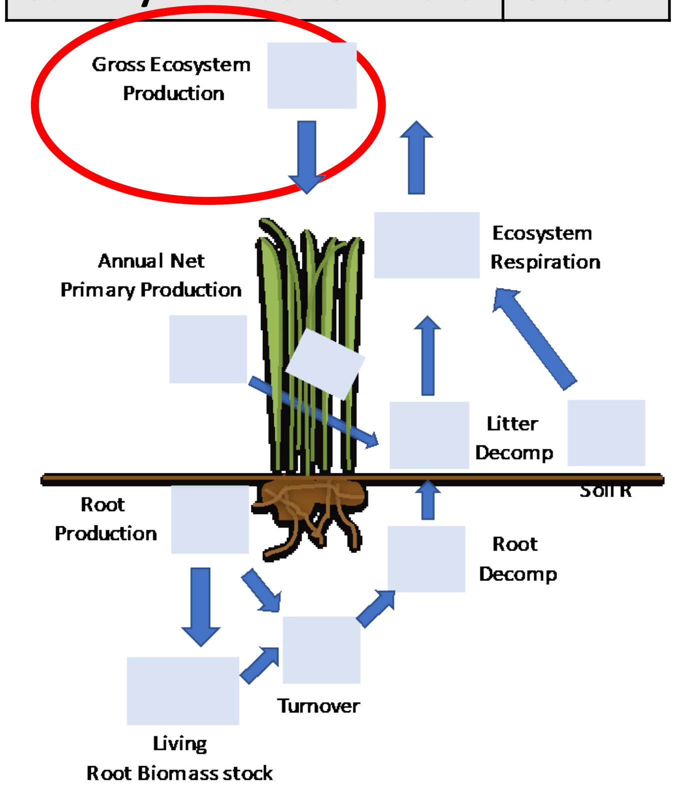
Gross Ecosystem Production



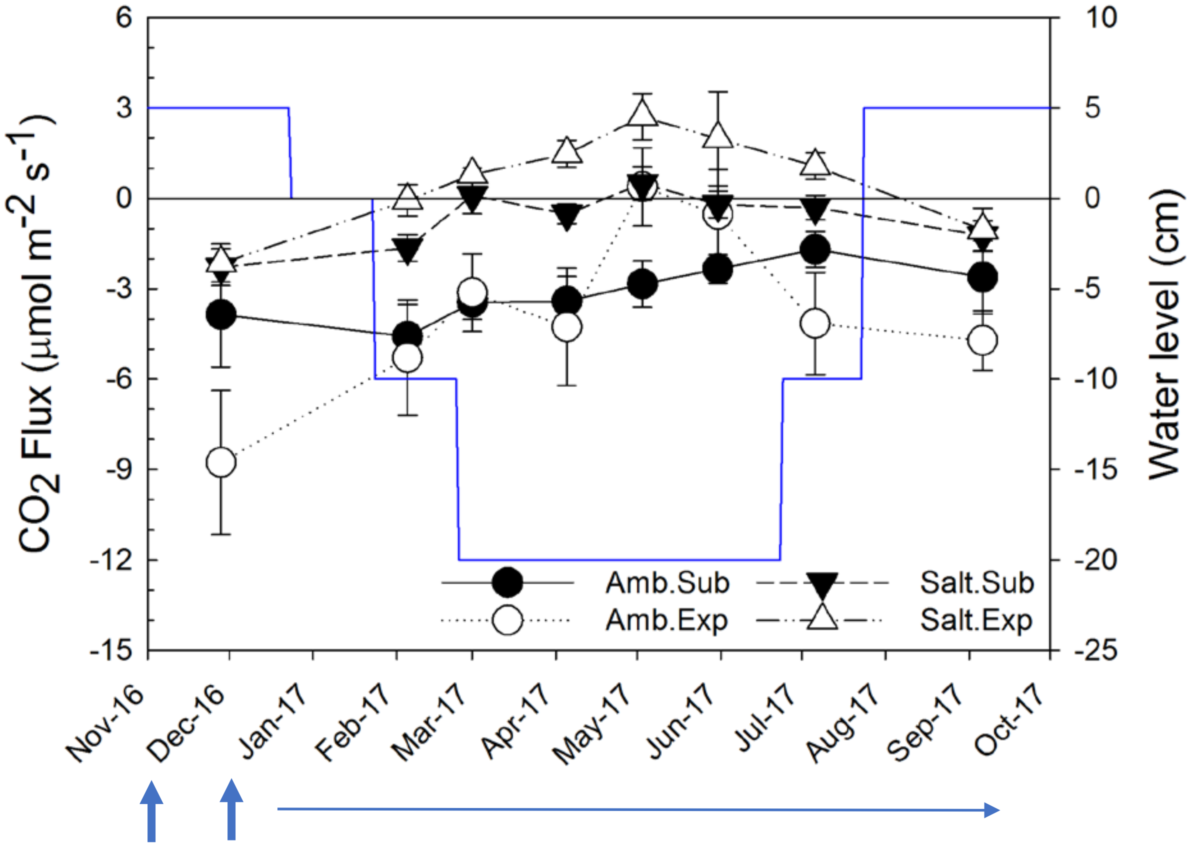
15 ppt 20 ppt

Amb = Ambient Salinity
Salt = Elevated Salinity
Sub = Submerged
Exp = Drought treatment

Salinity	**<0.001**
Inundation	0.062
Date	**<0.001**
Salinity*Inundation	0.090
Salinity*Date	**0.043**
Inundation*Date	**0.019**
Salinity*Inundation*Date	**0.038**



Net Ecosystem Production



15 ppt 20 ppt

Amb = Ambient Salinity

Salt = Elevated Salinity

Sub = Submerged

Exp = Drought treatment

Salinity	**0.002**
Inundation	0.669
Date	**<0.001**
Salinity*Inundation	0.312
Salinity*Date	0.156
Inundation*Date	**<0.001**
Salinity*Inundation*Date	**0.035**